

SCAP Spray Combustion Analysis Program

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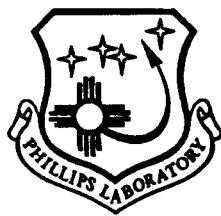
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FOREWORD

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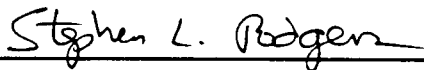
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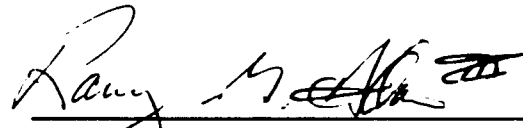
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13. ABSTRACT (MAXIMUM 200 WORDS) A computer program (SCAP) has been developed which determines the state of a propellant combustion mixture at any point along the axis of a bipropellant rocket engine. The combustion model is based upon the work of Priem and Heidmann and has been extended to treat generalized propellant and gas property data. The primary assumption of this method is that the propellant vaporization is the rate governing mechanism of the combustion process and that the vaporization of the drops can be expressed by a Ranza and Marshall type correlation. The governing equations consider mass, momentum, and heat transfer between the gas and liquid phases; and are cast in one dimension. The equations are represented by a set of ordinary differential equations and are solved simultaneously using the 4th order Runge-Kutta Adams-Moulton method. This report describes the program inputs and engineering methods for the SCAP computer code.				
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1.0 TECHNICAL DISCUSSION

1.1 Introduction

The steady-state Spray Combustion Analysis computer Program (SCAP) determines the state of the propellant combustion product mixture at any point along the axis of a liquid bipropellant rocket engine based on the evaporation rates of the propellants. The model is based on the vaporization model of Priem and Heidmann¹, with the exception that gasdynamics is treated in greater detail. The Computer Program also differs from the one presented in Reference 1 in that; 1) the different equations are integrated simultaneously rather than in nested loops and; 2) the program accepts general propellant and gas property data.

This version of SCAP is run as a module of both the VIPER² and TDK³ computer programs.

Necessary inputs to the program are propellant flow rate, temperature, injector velocity, physical properties, and drop size distribution of each propellant, and also the chamber pressure at the injector. Assuming steady-state operation, the program computes the condition of the propellants and combustion products by integrating (from the initial conditions at the injector) the continuity, momentum, and energy equations along the length of the chamber. The derivatives of all variables are determined explicitly using Euler integration. All physical properties are either input as tables, or computed automatically by subroutines.

The output of the steady-state program includes the annular stability parameters, i.e., burning rate parameter, drag parameter, relative velocity between droplets and gases, and the Reynolds number based on the speed of sound, that are required by the combustion instability model computer program described in Reference 4. This combustion instability model is an extension of the nonlinear analysis of combustion instability based on propellant vaporization that was originally developed by Priem and Guentert, Reference 5. Using the stability parameters provided by the steady-state program as a starting point, the combustion instability program will determine the minimum threshold disturbance required to trigger instability.

The methods of analysis used by the steady-state program are described below.

1.2 Method of Analysis

The basic model used in the Steady-State Combustion Program is an extension of the original work of Priem and Heidmann, Reference 1. The model considers the conservation equations governing the heat, mass, and momentum transfer of a spray of liquid oxidizer and fuel drops traveling through a channel filled with gas phase combustion products. The assumption is made that propellant vaporization is the rate governing mechanism of the combustion process and that vaporization of the drops can be expressed by a Ranz and Marshall type correlation,

Reference 6. The drops are injected at specified temperature and velocity, as a distribution about a mass median drop size into a quiescent chamber of combustion gases. As the drops vaporize mass into the combustion chamber the gas velocity increases. During this period the liquid temperature increases to its "wet bulb" value and the droplet velocities decrease because of drag forces. After the drops pass through the zero relative velocity region they are accelerated by the combustion gases.

1.2.1 Propellant Properties

An extensive set of properties must be provided to the program for each oxidizer/fuel combination. This is accomplished by reading the appropriate propellant properties deck, as described in Section 3. The required properties include: 1) the equilibrium composition of the combustion products, average molecular weight, and specific heat ratio as a function of pressure, temperature, and mixture ratio, 2) viscosity and specific heat for each species vs. temperature, 3) species molecular weight, 4) species and propellant interaction energies, 5) species and propellant molecular diameters, and 6) oxidizer and fuel liquid and vapor properties. At present the following propellant property combinations are provided with the program:

N ₂ O ₄ / N ₂ H ₄	,
N ₂ O ₄ / MMH	,
N ₂ O ₄ / A50	,
N ₂ O ₄ / UDMH	,
LOX / RP-1	,
LOX / g C ₃ H ₈	,
Air / JP4.	,
LOX / g H ₂	, and
LOX / g CH ₄	

1.2.2 Initial Conditions

The first step in the computer program is the establishment of the size and number distribution of the drops of each propellant to be used in the calculation. The drop size distribution for each propellant is determined by specifying the mass mean drop diameter, \bar{D} , a standard deviation σ_g , and the desired number of drop size groups, N. A drop radius vector, r, is then computed such that, assuming a log normal distribution as discussed in Reference 1, each propellant is divided into N groups of equal mass. Since the smallest drop group sometimes dominates a combustion instability analysis, it can be similarly subdivided into N_s groups, so that the total number of drop groups is $N_t = N + N_s - 1$.

Next, drop mass flux and number flux vectors are computed using the drop radius vector, the propellant density, and the injector mass flow rate for each propellant. Once these vectors have been determined, initialization of the calculation is essentially complete. The propellants

have each been divided into a large number of drops of different size groups with known mass, velocity, and temperature. With the other inputs to the program such as engine geometry and operating conditions, these drop properties are sufficient to calculate mass, heat, and momentum transfer between the drops and the combustion gases, and subsequent changes in conditions of combustion gases and drop properties as a result of these exchanges. Starting with the conditions at the injector, the calculations are integrated down the axis of the chamber to describe the conditions throughout.

1.2.3 Mass Transfer (Vaporization) for Drops

The rate of evaporation from a spherical drop of propellant A is assumed to be given by:

$$w_A = \frac{4\pi k_m M_A P_A}{\tilde{R} T_f} \ln \left[\frac{P}{P - P_A} \right] \quad (\text{lbm/sec}) \quad (1)$$

which is equivalent to the expression given by Priem in Reference 1. In the above equation:

w_A	=	transfer rate, mass of A per unit time	
r	=	radius of drop	(ft)
k_m	=	mass transfer coefficient, determined from the Nusselt number, Nu_m	
k_m	=	$Nu_m D_A r/2$	(ft ³ /sec) (2)
Nu_m	=	Nusselt number for mass transfer (Sherwood number)	
D_A	=	diffusivity of A at the conditions in the film	(ft ² /sec)
M_A	=	molecular weight of A	
P_A	=	vapor pressure of A. $P_A < P_{crit}$	
P	=	chamber pressure	(lbf/ft ²)
\tilde{R}	=	universal gas constant	
T_f	=	average absolute temperature in the vapor film between the drop and the bulk gas	
		$T_f = \frac{T_L + T_g}{2}$	(°R)
T_L	=	liquid drop temperature	(°R)
T_g	=	bulk gas temperature	(°R)

The Nusselt number for mass transfer is determined from the Ranz and Marshall equation (see Reference 6, page 647):

$$Nu_m = 2 + 0.6 Re_f^{1/2} Sc_f^{1/3} \quad (\text{unitless})$$

where

$$\begin{aligned}
\text{Re}_f &= \text{Reynolds number, evaluated at film conditions, i.e.} \\
\text{Re}_f &= \frac{2r\rho_f|U - V|}{\mu_f} & (\text{unitless}) & (4) \\
\rho_f &= \text{density of the gas in the film} & (\text{lbm/ft}^3) & \\
\mu_f &= \text{viscosity of the gas in the film} & (\text{lbm/ft-sec}) & \\
U &= \text{velocity of the combustion gas} & (\text{ft/sec}) & \\
V &= \text{velocity of the drop} & (\text{ft/sec}) & \\
\text{Sc}_f &= \text{Schmidt number evaluated at film conditions} & & \\
& \quad (\text{Reference 6, page 512), i.e.} & & \\
\text{Sc}_f &= \frac{\mu_f}{\rho_f D_A} & (\text{unitless}) & (5)
\end{aligned}$$

Knowing the Nusselt number, k_m can be evaluated and w_A for the drop determined.

The time rate of change of the mass of a drop is simply

$$\frac{dm}{dt} = -w_A \quad (\text{lbm/sec}) \quad (6)$$

Knowing the evaporation rate, only the heat transfer rate is required to complete an energy balance for the drop and determine the effect of net energy exchange on the drop temperature.

1.2.4 Heat Transfer Model

The rate of heat transferred to the drop by convection is determined by the equation

$$Q_c = 4\pi r^2 h^\circ (T_g - T_L) \quad (\text{BTU/sec}) \quad (7)$$

where

$$\begin{aligned}
Q_c &= \text{heat per unit time transferred by convection} \\
h^\circ &= \text{convective heat transfer coefficient corrected for} \\
& \quad \text{the effect of concurrent mass transfer}
\end{aligned}$$

From film theory (Preim, Reference 1, eq. 22 and 20) h° can be related to h , the heat transfer coefficient with no mass transfer by

$$\begin{aligned}
h &= \text{Nu}_h k_f / 2r & (\text{BTU/sec-ft}^2\text{-R}) & (8) \\
h^\circ &= h \left[\frac{z}{e^z - 1} \right]
\end{aligned}$$

where (Reference 1, eq. 16)

$$z = \frac{w_A C_{PAf}}{4\pi r^2 h} \quad (\text{unitless}) \quad (10)$$

C_{PAf} = specific heat of vapor of A at the film conditions. (BTU/lbm-R)

The heat transfer coefficient without mass transfer, h , is determined from the Ranz-Marshall equation (Reference 1, eq. 22).

$$Nu_h = 2 + 0.6 Re_f^{1/2} Pr_f^{1/3} \quad (\text{unitless}) \quad (11)$$

where Re_f is determined by equation (4), and

$$\begin{aligned} Pr_f &= \text{Prandtl number evaluated at film conditions, i.e.} \\ Pr_f &= \frac{C_{PAf} \mu_f}{k_f} \\ k_f &= \text{thermal conductivity of the gas in the film} \end{aligned} \quad (\text{BTU/ft-sec-R}) \quad (12)$$

When the convective heat transfer to the drop has been determined, an energy balance for the drop will give the rate of change of temperature of the drop.

1.2.5 Energy Balance for Drops

For any single drop the rate of accumulation of energy at any time must equal the net energy transferred to the drop. By equation this is expressed as

$$m C_{PL} \frac{dT_L}{dt} = Q_c - w_A \lambda - \frac{w_A v_{rad}^2}{2Jg} \quad (\text{BTU/sec}) \quad (13)$$

where

$$\begin{aligned} m &= \text{mass of drop} \\ C_{PL} &= \text{specific heat of liquid at } T_L \\ \lambda &= \text{latent heat of vaporization at } T_L \\ v_{rad} &= \text{radial velocity of vaporized propellant leaving the drop surface} \\ &\quad v_{rad} = w_A / \rho_{vap} \quad S, \quad S = 4\pi r^2 \\ J &= \text{constant for conversion of mechanical energy to thermal energy} \end{aligned}$$

In applying this equation it is assumed that the drop has uniform temperature throughout due to rapid internal convection. The third term on the right side of the equation is the kinetic energy imparted to the vapor leaving the surface. Most investigators have not included this term since it is usually relatively small. It has been included here since it could be important for small radii and/or when the drop is near or at the critical temperature of the propellant and λ approaches or equals zero.

From equation (13) the rate of change of the drop temperature with time, or distance, can be evaluated.

The procedure just described to determine the mass-transfer rate and then determine the change in temperature of the drop is the one normally employed in the program. However, when the drop temperature approaches the boiling point of the liquid, a second procedure is used in order to eliminate the numerical difficulties associated with $P - P_A$ approaching zero in the denominator of equation (1). Under these circumstances the energy transfer to the drop determines the rate of vaporization, w , which can be found by evaluating properties at T_L equal to the liquid boiling point at the chamber pressure and by setting $\frac{dT_L}{dt} = 0$. Equation (13) is then solved for w .

The only remaining calculation is to determine the rate of change of velocity of the drop as a result of momentum exchange with the combustion gas.

1.2.6 Force Balance for Drops

A force balance on the drop yields the equation

$$\rho_L \frac{4}{3} \pi r^3 \frac{dV}{dt} = \pi r^2 C_D \rho \frac{(U - V)|U - V|}{2} \quad (14)$$

ρ_L	=	drop density
V	=	drop velocity
C_D	=	drag coefficient
ρ	=	gas density
U	=	gas velocity

The drag coefficient is found as a function of Reynolds number:

$$\begin{array}{lll} C_D & = & \min(27 Re_f^{-.84}, 50) & 0 \leq Re_f < 80 \\ C_D & = & .271 Re_f^{.217} & 80 \leq Re_f < 10^4 \\ C_D & = & 2 & Re_f \geq 10^4 \end{array} \quad (15)$$

From equations (7), (13), and (14), and since $dt = dx/V$, the differential equations governing drop mass, drop temperature, and drop velocity, are found to be:

$$\frac{dm}{dx} = -\frac{w}{V} \quad (16)$$

$$\frac{dT_L}{dx} = \frac{Q_c - w\lambda - \frac{w v_{rad}^2}{2J}}{mVC_{PL}} \quad (17)$$

and

$$\frac{dV}{dx} = \frac{3}{8} \frac{1}{r} \frac{\rho}{\rho_L} \frac{|U - V|(U - V)}{V} C_D \quad (18)$$

1.2.7 Equations for Steady State Combustion

For one-dimensional steady state flow, consideration of fluxes in and out of an incremental length, dx , along the combustion chamber lead to expressions for continuity, momentum, and energy at any point.

The continuity equation can be expressed as

$$\overset{\text{(gas flux)}}{\Phi} + \overset{\text{(particle flux)}}{\sum n_i m_i} = \overset{\text{(total feed)}}{F_T} \quad (19)$$

where

$$\begin{aligned} \Phi &= \rho UA, \text{ gas mass flux} \\ \rho &= \text{gas density} \\ U &= \text{gas velocity} \\ A &= \text{the local cross-sectional area of the chamber} \\ n_i &= \text{number flux, i.e., the number of drops of mass } m_i \text{ flowing per unit time} \\ &\quad \text{past position } x. \text{ (1/sec)} \\ &\quad n_i = (\text{no. of drops in group } i)(\text{feed rate for group } i)/(\text{mass in group } i) \\ m_i &= \text{mass of the } i\text{th drop} \\ F_T &= \text{total propellant feed rate, lbs/sec.} \\ &\quad F_T = F_{ox} + F_{fuel} \end{aligned} \quad (20)$$

It follows that

$$\frac{d\Phi}{dx} + \sum n_i \frac{dm_i}{dx} = 0 \quad (21)$$

so that

$$\frac{dU}{dx} = -\left(\frac{U}{A} \frac{dA}{dx}\right) - \left(\frac{U}{\rho} \frac{d\rho}{dx}\right) - \left(\frac{1}{\rho A} \sum n_i \frac{dm_i}{dx}\right) \quad (22)$$

The momentum equation can be expressed as

$$-Ag \frac{dP}{dx} = \frac{d\Phi U}{dx} + \sum n_i \frac{dm_i V_i}{dx} \quad (23)$$

where

$$\begin{aligned} g &= \text{gravitational constant, } 32.174 \text{ ft/sec}^2 \\ P &= \text{pressure} \\ V_i &= \text{velocity of the } i\text{th drop} \end{aligned}$$

Since equation (21) gives

$$\frac{d\Phi}{dx} = -\sum n_i \frac{dm_i}{dx}$$

it follows that

$$\frac{dP}{dx} = +\frac{U}{Ag} \sum n_i \frac{dm_i}{dx} - \frac{\rho U}{g} \frac{dU}{dx} - \frac{1}{Ag} \left[\sum n_i m_i \frac{dV_i}{dx} + \sum n_i V_i \frac{dm_i}{dx} \right] \quad (24)$$

The energy equation used by the steady-state program is simply:

$$T = T_o - \frac{\gamma - 1}{2\gamma} \frac{U^2}{gR} \quad (25)$$

where

$$\begin{aligned} T &= \text{gas temperature} \\ T_o &= \text{gas total temperature} \\ \gamma &= \text{gas specific heat ratio} \\ R &= \text{gas constant, } \tilde{R} / M_w \\ M_w &= \text{gas molecular weight} \end{aligned}$$

It follows that

$$\frac{dT}{dx} = \frac{dT_o}{dx} - \frac{1}{gR} \left[\frac{\gamma - 1}{\gamma} U \frac{dU}{dx} + \frac{\gamma - 1}{2\gamma} \frac{U^2}{M_w} \frac{dM_w}{dx} + \frac{U^2}{2\gamma^2} \frac{d\gamma}{dx} \right] \quad (26)$$

The equation of state used by the steady-state program is

$$P = \rho R T \quad (27)$$

It follows that:

$$\frac{d\rho}{dx} = \frac{1}{RT} \frac{dP}{dx} - \frac{P}{RT^2} \frac{dT}{dx} + \frac{P}{TRM_w} \frac{dM_w}{dx} \quad (28)$$

The differential equations previously described are solved as a set of $(1 + N_{ox} + N_{fuel})$ simultaneous ordinary differential equations using the 4th order Runge-Kutta Adams-Moulton integration method (see Subroutine RKAM). The form the equations take is given below.

For the gas phase, a single ordinary differential equation (the momentum equation) is given by equation 24, and is repeated here for convenience.

$$\frac{dP}{dx} = + \frac{U}{Ag} \sum n_i \frac{dm_i}{dx} - \frac{\rho U}{g} \frac{dU}{dx} - \frac{1}{Ag} \left[\sum n_i m_i \frac{dV_i}{dx} + \sum n_i V_i \frac{dm_i}{dx} \right]$$

The terms U , ρ , T , du/dx , dp/dx , and dT/dx are determined from equations 19, 27, 25, 22, 28, and 26, respectively.

$$U = (F_T - \sum n_i m_i) / \rho A$$

$$\rho = P/RT, \quad R = R/M_w$$

$$T = T_o - \frac{\gamma - 1}{2\gamma} \frac{U^2}{gR}$$

$$\frac{dU}{dx} = - \frac{U}{A} \frac{dA}{dx} - \frac{U}{\rho} \frac{d\rho}{dx} - \frac{1}{\rho A} \sum n_i \frac{dm_i}{dx}$$

$$\frac{d\rho}{dx} = \frac{1}{RT} \frac{dP}{dx} - \frac{P}{RT^2} \frac{dT}{dx}$$

$$\frac{dT}{dx} = \frac{dT_o}{dx} - \frac{1}{gR} \frac{\gamma - 1}{\gamma} U \frac{dU}{dx}$$

Note that the terms dM_w/dx and $d\gamma/dx$ in equations (26) and (28) are neglected. These terms have been found to be so small that no significant error results from their elimination.

For the condensed phase there are $N_{ox} + N_{fuel}$ ordinary differential equations (ODE's) as given by equations (16), (17), and (18), as follows:

$$i = 1, 2, \dots, N_{ox}, \dots, N_{ox} + N_{fuel}$$

$$\frac{dm_i}{dx} = - \frac{w_i}{V_i} \quad (29)$$

$$\frac{dT_{L,i}}{dx} = \frac{Q_{c_i} - w_i \lambda_i - w_i v_{rad}^2 / 2J}{m_i V_i C_{PL,i}} \quad (30)$$

$$\frac{dV_i}{dx} = \frac{3}{8} \frac{1}{r_i} \frac{\rho}{\rho_{L,i}} \frac{(U - V_i)|U - V_i|}{V_i} C_{D,i} \quad (31)$$

The methods used to obtain initial values for the above ODE's are described below. Initial values are required for the state variables, which are P, U, ρ , and T for the gas phase, and m_i , $T_{L,i}$, and V_i ($i = 1, 2, \dots, N_{ox} + N_{fuel}$) for the condensed phase.

The initial values for the gas phase are set as:

$$\begin{aligned} P &= \text{input} \\ U &= \text{input} \\ \rho &= P/RT \end{aligned}$$

where

$$\begin{aligned} R &= \tilde{R} / M_w \\ M_w &= M_w (O/F) \\ \text{and } (O/F) &= \text{input (default: } (O/F) = F_{ox}/F_{fuel}) \\ T &= T(O/F) \end{aligned}$$

From the above it can be seen that the initial value for the gas phase mass flow is

$$\Phi = \rho U A$$

The input feed rate to the system must be adjusted to provide mass conservation. The adjusted values are

$$\begin{aligned} F'_{ox} &= F_{ox} - \left[\frac{O/F}{O/F + 1} \right] \Phi \\ F'_{fuel} &= F_{fuel} - \left[\frac{1}{O/F + 1} \right] \Phi \\ F'_T &= F'_{ox} + F'_{fuel} = F_T - \Phi \end{aligned}$$

The initial values for the condensed phase m_i , $T_{L,i}$, and V_i are obtained as described below. A single initial value of temperature and of velocity is input for each propellant; $T_{L,ox}$, $T_{L,fuel}$, V_{ox} , and V_{fuel} . These initial values apply to all oxidizer drops and to all fuel drops, respectively. A single mass median drop size is also input for each propellant; \bar{D}_{ox} and \bar{D}_{fuel} . A drop size distribution for the oxidizer and for the fuel is then calculated as discussed in Section 1.2.2. Since the radius of the drops in the i th group is now known, drop volumes for the i th group are calculated as

$$VOL_i = \frac{4}{3} \pi r_i^3 .$$

The mass of each drop is

$$m_i = \rho_i VOL_i$$

where

$$\rho_i = \rho_i (T_{L,i}) .$$

Initial values are also needed for the drop group number flux, n_i , which is the number of drops of mass m_i flowing per second past the initial position. The adjusted feed rate for each propellant, \dot{F}_{ox} and \dot{F}_{fuel} , is used to calculate the n_i . For the oxidizer

$$n_{ox,i} = \dot{F}_{ox,i} / m_{ox,i} \text{ (sec}^{-1}\text{)}$$

where

$$\dot{F}_{ox,i} = (\text{mass fraction of oxidizer in group i}) \dot{F}_{ox}$$

Values for the fuel are calculated in the same manner.

1.2.9 Analysis with 2D Droplet Velocity

TRW Inc. has developed a class of engines which feature a pintle injector design in which the spray pattern is not directed axially. The figure given below illustrates the injection process for a typical pintle injector design.

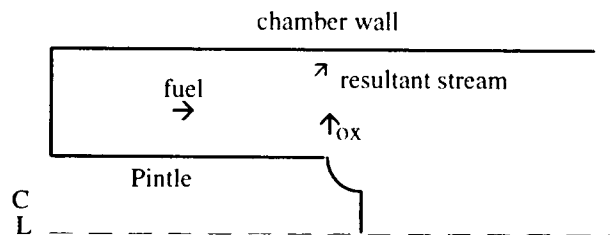


Figure 1. Schematic, TRW Pintle Injector Spray

The injector produces a cylindrical fuel sheet that is axially directed along the outer wall of the pintle. Oxidizer is injected near the end of the pintle in the radial direction as a planar sheet. It can be assumed that the impingement of these streams produces a single sheet of oxidizer and fuel directed along the resultant momentum path, and is, therefore, shaped as a conic frustum.

A method has been provided in the code by which this type of flow can be approximated. The method assumes that gas velocity, U , is directed axially, as before. However, the oxidizer and fuel sprays are assumed directed initially along a common, non-axial, path (the path of resultant momentum). Thus, each drop group velocity, V_i , is represented by two components, u_i and v_i . The velocity and distance vectors are represented as shown in the figure given below.

$\theta_i = \arctan v_i/u_i$ $t_i = \int \frac{1}{V_i} dS_i$ $dS_i = dx / \cos \theta_i$ $dt_i = dS_i / V_i = \frac{dx}{V_i \cos \theta_i}$	
---	--

Figure 2. 2D Model: Velocity, Distance, and Time of Flight for the i th Drop Group

The equations given previously are then modified as shown below.

- $V_i^2 = u_i^2 + v_i^2$

and

$$\theta_i = \arctan (v_i / u_i)$$

- In equation (24), u_i replaces V_i
- In equation (29) and (30), $V_i \cos \theta_i$ replaces V_i
For example:

$$\frac{dm_i}{dx} = - \frac{w_i}{V_i \cos \theta_i} \quad (32)$$

- Equation (31) is replaced by

$$\frac{du_i}{dx} = \frac{3}{8} \frac{1}{r_i} \frac{\rho}{\rho_{Li}} \frac{(U - u_i)|U - u_i|}{u_i} \quad (33)$$

and

$$\frac{dv_i}{dx} = \frac{3}{8} \frac{1}{r_i} \frac{\rho}{\rho_{Li}} \frac{-v_i |v_i|}{u_i}$$

The TRW LM Descent Engine (LMDE), and its derivative, the TR-201, feature a pintle injector in which the oxidizer is injected as radial spokes, rather than as a sheet. A photograph of the LMDE pintle tip is shown below (from Reference 7).

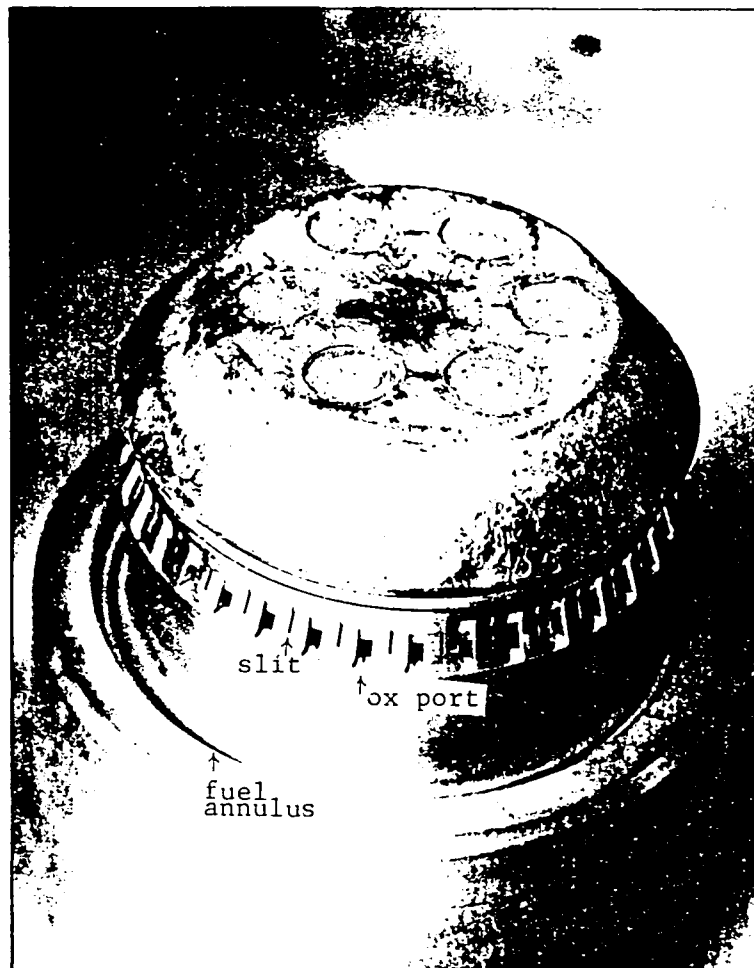


Figure 3. Post Test Photograph of Injector and Pintle Tip
for Engine No. 1/No. 3, HEA (S/N 023) - After Approximately
2390 Seconds of Firing Time (13738-66)

Note that two types of oxidizer injection ports are used. There are 36 nearly square ports that are bisected by 36 much smaller slit shaped ports. The latter are displaced slightly downstream of the former. This type of injection scheme can be simulated by the method described below.

The fuel modeled as three drop groups which result from, 1) fuel sheet impingement with oxidizer injected from the larger ports, 2) fuel sheet impingement with oxidizer injected from the smaller ports, and 3) break-up of the non-impinging portion of the fuel sheet. The oxidizer is modeled as two drop groups, corresponding to situations 1 and 2, above. The axial position of the atomization surface is assumed to be the same for each drop group. Thus, there will be three resultant momentum streams, illustrated in Figure 4, below.

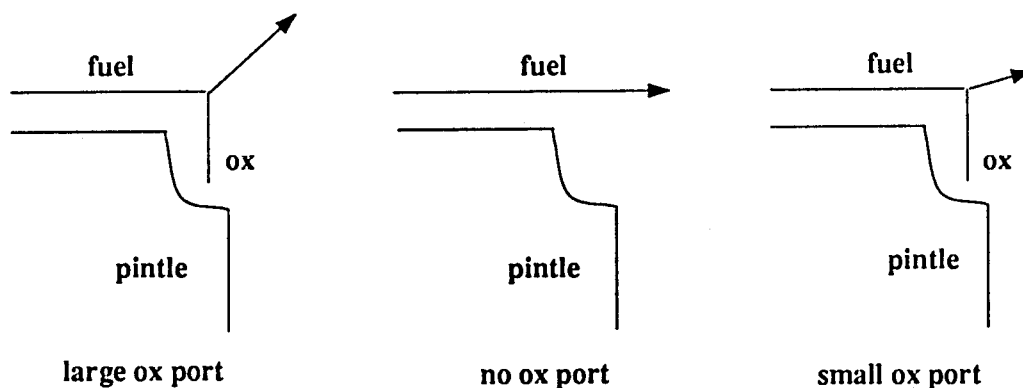


Figure 4. Momentum Streams Resulting from Two Oxidizer Spokes Impinging on a Cylindrical Fuel Sheet

1.2.10 Calculation of Mixture Viscosity, Specific Heat, and Thermal Conductivity

The viscosity of the gas mixture, μ , is calculated by the method of Wilke which is described on page 24 of Reference 6.

For the viscosity of the gas film around the propellant drops, an arithmetic average of the bulk product gas and the fuel vapor both taken at the film temperature is used. The viscosities of the individual gas species are provided as data.

The specific heat of the gas mixture, C_p , is taken as the molar average of the specific heats of the species present.

The thermal conductivity of the gas mixture, k , is calculated by Eucken's equation which is described on page 257 of Reference 6.

$$k = \left(c_p + \frac{5}{4} R \right) \mu \quad , \quad R = \tilde{R} / M_w$$

Values for the gas mixture viscosity, specific heat, and thermal conductivity are calculated in the program by subroutine VKSGAS.

1.2.11 Calculation of Vapor Diffusivity

Diffusivity of the oxidizer through the mixture, or of the fuel through the mixture, is calculated using the methods described in Reference 6. Usage of the Lennard-Jones parameters are as described on page 511, using the tables presented in Appendix B of Reference 6, especially Table B-2, page 746. The diffusivity is calculated using Wilkes equation; i.e., equation (18.4-25) on page 571 of Reference 6. These calculations are carried out by subroutine DIFFU.

1.2.12 Stability Parameters

Stability parameters ΔV , L , Re_d , and D are calculated for each of the oxidizer and fuel sprays as follows:

Relative Mach number, ΔV , between gas and liquid:

$$\Delta V = (U - V) / a$$

where

$$a = \text{local speed of sound}$$

Burning rate parameter (L) which is defined as:

$$L = r_{an} f / \epsilon_c$$

where

$$r_{an} = \text{radius of annulus}$$

f = burning rate (fraction/inch)

$$f = - \left[\sum n_i \frac{dm_i}{dx} \right] / \dot{w}$$

\dot{w} = propellant flow rate

ϵ_c = nozzle contraction ratio

Reynolds Number (Re_d):

$$Re_d = 2ra \rho / \mu$$

Drag Parameter (D):

$$D = \frac{3}{8} \frac{r_{an}}{A} \sum \frac{C_{Di} n_i m_i}{\rho V_i r}$$

These quantities are calculated in subroutine PRINT.

1.2.13 SCAP - ODK Linkage

Fuel and/or Oxidizer vaporization profiles are provided by SCAP for input to the ODK module of either VIPER or TDK. The profiles are given as a function of path length, x , in the form

$$[C_L] / [C_L]_0 = f(x).$$

The function, $f(x)$ is obtained as described below.

The continuity equation for the combustion chamber can be written as

$$\phi_g + \phi_L = F_T$$

where ϕ_g and ϕ_L are the gas phase and liquid phase mass flow rates at any chamber cross section. The quantity F_T is the total propellant flow rate into the injector (total feed as measured by the ox and fuel flow meters, $F_T = F_{ox} + F_{fuel}$).

Since

$$\phi_L = [1 - \eta_{vap,ox}] F_{ox} + [1 - \eta_{vap,fuel}] F_{fuel}$$

it follows that

$$\begin{aligned} C_{\text{gas}} &= \phi_g / F_T \\ C_{\text{L,ox}} &= [1 - \eta_{\text{vap,ox}}] F_{\text{ox}} / F_T \\ C_{\text{L,fuel}} &= [1 - \eta_{\text{vap,fuel}}] F_{\text{fuel}} / F_T \end{aligned}$$

and

$$C_{\text{gas}} + C_{\text{L,ox}} + C_{\text{L,fuel}} = 1.$$

Using these quantities a table of $f(x)$ vs x is output such that

$$[C_L] / [C_L]_0 = f(x).$$

This output is done both for ox and fuel.

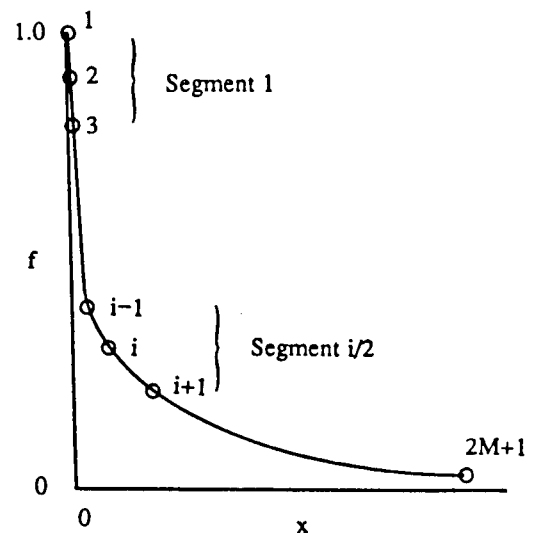
The quantity $[C_L]_0$ is taken at $x = x_0$, which is reached when the gas phase mixture ratio is equal to an input value, (OFEQ). The idea here is that the gas phase is initially in a state of equilibrium since it is oxidizer rich due to the relatively low vapor pressure of the oxidizer as compared to the fuel. It is well known that oxidizer/fuel mixtures usually combust to an equilibrium product as long as the mixture ratio is not excessively fuel rich.

Since the table $f(x)$ vs x is not always smooth and can contain many entries (more than 1000), and also since the derivative quantities f' and f'' are required, it is useful to prepare curve fits of the results. The method used here for curve fitting the data is described below.

The function, f , to be fit is shown in the adjacent figure. Note that $f(0) = 1$ and then decays monotonically; but may or may not reach zero (100% vaporization). The function is defined by many points in a table. The fit, however, is made using a few points obtained by interpolation. The form of the fit is

$$F = \frac{A}{X + \epsilon} + B + CX$$

where ϵ is a small number used to remove the singularity at $x = 0$. The curve fit coefficients (A, B, C) are determined from:



$$\begin{bmatrix} \frac{1}{X_{i-1}+\epsilon} & 1 & X_{i-1} \\ \frac{1}{X_i+\epsilon} & 1 & X_i \\ \frac{1}{X_{i+1}+\epsilon} & 1 & X_{i+1} \end{bmatrix} \begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} f_{i-1} \\ f_i \\ f_{i+1} \end{bmatrix} .$$

Here, the curve defined by f is divided into N segments. An odd number of points, $M = 2N+1$, are obtained by interpolation and a three point fit is computed for each segment.

It follows that

$$\begin{aligned} f' &= -A(X+\epsilon)^{-2} + C \\ \text{and} \\ f'' &= 2A(X+\epsilon)^{-3} . \end{aligned}$$

2.0 PROGRAM DESCRIPTION

The Steady-State computer program consists of a main program and the subroutines listed below. Subroutines supplied the operating system and the plot software are not listed.

Callable Subroutines (see Figure 5)

SCD, SCAP control subroutine

ALM

BOIL

COMP

DIFFU, see Section 1.2.11

DIST1

DROP

ERFIN

FGAM

GDERIV

IN

INITPL

KFIT

LINI

LINIR

LNGRIN

LOGDIS

MASS

OUT

PDROP

PLOTM

PLOTPROP

PLOTT

PRINT

RKAM

RSET

SCDERIV

SCPRNT

SCPROP

SCSTREAM

SGECO

SGESL

SPLOT

TGINT

UTDROP

VAPOR

VKSGAS, see Section 1.2.10

WTMINT

YDY

Function Subroutines

CD
CPL
CVAP
FKA
PVAP
RHO
RT
TBL
VISCV

Thirteen of the above subroutines are used to obtain properties for the oxidizer, fuel, and combustion product gas.

These subroutines are described briefly in Tables 1 and 2, respectively.

Descriptions of some of the more important Fortran variables are given in Table 3. Throughout the program the index I=1 is used for oxidizer, and the index I=2 is used for fuel. As many as 20 drop groups can be used for each propellant. Thus, in Table 4 a dimension of (20,2) refers to (drop groups, propellant).

Plotting is accomplished by using calls to the plot software subroutines AXIS, LINE, NUMBER, PLOTS, etc.

Several subroutines are described in more detail at the end of this section.

Table 1. Propellant Properties Function Subroutines

<u>Subroutines</u>		<u>Property (Units)</u>	<u>Independent Variable (Units)</u>
ALM	λ_A	heat of vaporization (BTU/lb)	liquid temperature ($^{\circ}\text{R}$)
CPL	C_P	liquid specific heat (BTU/lb- $^{\circ}\text{R}$)	liquid temperature ($^{\circ}\text{R}$)
CVAP	C_{P_v}	vapor specific heat (BTU/lb- $^{\circ}\text{R}$)	temperature ($^{\circ}\text{R}$)
FKA	k_A	vapor thermal conductivity $\times 10^6$ (lbm/in-sec- $^{\circ}\text{R}$)	temperature ($^{\circ}\text{R}$)
PVAP	P_A	vapor pressure (psia)	liquid temperature ($^{\circ}\text{R}$)
RHO	ρ_L	liquid density (lb/in 3)	liquid temperature ($^{\circ}\text{R}$)
TBL	T_{BL}	boiling temperature ($^{\circ}\text{R}$)	pressure (psia)
VISCV	μ_A	vapor viscosity $\times 10^6$ (lbm/in-sec)	temperature ($^{\circ}\text{R}$)

Table 2. Combustion Species Properties Subroutines

<u>Subroutines</u>		<u>Property (Units)</u>
COMP		combustion gas composition (mole fraction) vs O/F ratio at 3 different pressures (psia)
DIFFU	D	calculates diffusion coefficient of fuel and oxidizer through combustion mixture
		Lennard Jones Parameters
	σ_1	atomic radius of oxidizer (°A)
	σ_2	atomic radius of fuel (°A)
	σ_j	atomic radius for each species (°A)
	ϵ_1/k	interaction energy of oxidizer (°K)
	ϵ_2/k	interaction energy of fuel (°K)
	ϵ_j/k	interaction energy for each species (°K)
TGINT	T_o	flame temperature (°R) vs O/F ratio at 3 different pressures (psia)
VKSGAS	μ	viscosity (lbm/in-sec) vs temperature (°R) for each species
	C_p	specific heat (BTU/mole-°R) vs temperature (°R) for each species
	k	thermal conductivity, BTU-in-sec-°R
	Mw_j	molecular weight of each species
WTMINT	M_w	combustion gas molecular weight

Table 3. Fortran Variable Descriptions

<u>FORTTRAN NAME</u>	<u>SYMBOL</u>	<u>DESCRIPTION</u>
AX	A_c	chamber cross-sectional area, function of x, calculated in STREAM
AXMIN	A_t	area of throat
FUNCTION CD	C_d	drag coefficient
	C_p	heat capacity:
FUNCTION CPL		- of liquid
FUNCTION CVAP		- of vapor
CPA		- of vapor at average mantle temperature
CPB		- of bulk products at average mantle temperature
CPG		- of bulk products at static temperature
CPAV		- of mantle mixture
DFU	D	molecular diffusion coefficient
DM (20,2)		dm_{ji}/dx
DN (20,2)	n_{ji}	number of drops/sec. in each drop size group
DT (20,2)		$dT_{L,ji}/dx$
DV (20,2)		dV_{ji}/dx
EM (20,2)	m_{ji}	mass of drop
EMD	\dot{F}_T	feed flow rate, total, $\dot{F}_T = \dot{F}_{ox} + \dot{F}_{fuel}$
ENDOT(2)	W_i	feed flow rates, ox and fuel, (lbm/sec)
ENPM(2)	$-w_i$	$= \sum n_j dm_{ji}/dx$
ETA	ϵ_c	nozzle contraction ratio
	k	thermal conductivity
FUNCTION FKA		- of vapor
FKB		- of bulk products at average mantle temperature
FKG		- of bulk products at static temperature
FKAV		- of mantle mixture at average temperature
FNUH (20,2)	Nu_h	Nusselt number, heat transfer
FNUM (20,2)	Nu_m	Nusselt number, mass transfer
FVAP		Total propellant fraction vaporized
FVAP1		local oxidizer fraction vaporized
FVAP2		local fuel fraction vaporized
GAM	γ	ratio of specific heats of product gas
NSSET(2)	n_i	number of drop groups, oxidizer and fuel

Table 3. Fortran Variable Descriptions (continued)

<u>FORTTRAN NAME</u>	<u>SYMBOL</u>	<u>DESCRIPTION</u>
P	P	static bulk gas pressure
PA	P	vapor pressure, calculated by Function PVAP
PHI	Φ	gas mass flow rate, $\Phi = \rho UA$
PR (20,2)	Pr	Prandtl number
R	\tilde{R}	universal gas constant, subroutine REED
RAT	o/f	mixture ratio = EMDOT(1)/EMDOT(2)
RG	R	gas constant, \tilde{R}/m_w
	Re	drop Reynolds number
RE (20,2)		- bulk gas properties
REP (20,2)		- mantle properties
	ρ	density
RH		- of liquid, calculated by function RHØ
RHOG		- of bulk gas at static temperature
RHOAV		- of mixture in mantle at average temperature
RM(2)	r_m	radius of mass median droplet
RS (20,2)	r	drop radius
FUNCTION RT	r_t	distance from drop surface to decomposition flame
RVAP	f	vaporization rate of spray (fraction/in.)
SC (20,2)	Sc	Schmidt number
SDSPD	a	speed of sound
TB	T_b	boiling point temperature, calculated by function TBL
	T	temperature
TG		- static gas, T_g
TL (20,2)		- liquid, T_{Lji}
TSTG		- stagnation, T_{g0}
TWB	T_{wb}	wet bulb temperature in subroutine TWFL
U	U	gas velocity
V (20,2)	V_{ji}	drop velocity
VD (20,2)	$U-V_{ji}$	gas-drop relative velocity
	μ	viscosity, calculated by subroutine VKSGAS
VIS		- of bulk products at static temperature
VISB		- of bulk products at average mantle temperature

Table 3. Fortran Variable Descriptions (concluded)

<u>FORTTRAN NAME</u>	<u>SYMBOL</u>	<u>DESCRIPTION</u>
VISAV		- of mantle mixture at average temperature
WCON(2)		$2\pi M_{w,i}/R$
WTML	M	molecular weight of vapor, calculated by subroutine WTMINT
WTMAV		- of mantle mixture
WTMOL		- of propellant, input
WW (20.2)	w_{ji}	vaporization rate of single drop (lbm/sec)
X	x	axial position (usually $x=0$ at injector)
XL	K	evaporation rate constant, calculated by function XK
Z	z	correction factor for mass transfer, defined by equation (10)

SUBROUTINE DIST1

Input: \bar{D}, N, σ_g

Output: $D_j, (2j-1)/2N$; $j = 1, \dots, N$

Description:

Given an arbitrarily large number of spherical drops of mass mean diameter, \bar{D} , which are assumed to possess a logarithmic normal distribution about \bar{D} , then the distribution of mass of drops as a function of size is described by:

$$\frac{df}{dD} = \left[(2\pi)^{1/2} D \ln \sigma_g \right]^{-1} \exp \left[-\frac{1}{2} \left(\frac{\ln \frac{D}{\bar{D}}}{\ln \sigma_g} \right)^2 \right] \quad (a)$$

where

D is drop diameter
f is the fraction of mass in drops smaller than D
 σ_g is the geometric standard deviation.

The purpose of this subroutine is to determine a set of N drop diameters

D_j ; $j = 1, \dots, N$

such that

$$\int_0^{D_j} \left(\frac{df}{dD} \right) dD = \frac{2j-1}{2N} \quad (b)$$

For example, if $\bar{D} = 30$ microns, then integrating equation (a) will yield values of f as indicated by the solid line in Figure 6. If this distribution is then replaced by $N=5$ discrete drop groups, then the resulting distribution will be as indicated by the dash line in the figure where equation (b) is used to obtain the particle group diameters, D_j .

The method solves equation (b) directly, using the inverse error function (subroutine ERFIN).

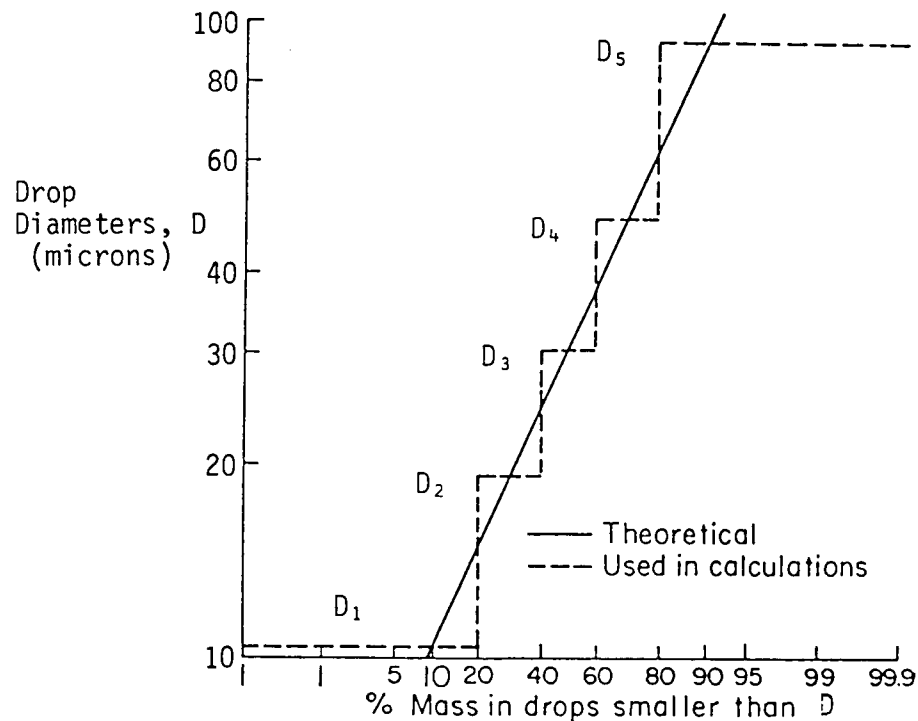


Figure 6. Drop Size-mass Distribution for Standard Deviation of 2.3, Reference 1.

FUNCTION ERFIN(ERF)

The inverse error function is calculated using a rational polynomial approximation. Given a value of the error function, $\text{erf}(z)$, the corresponding value of z is found as described below. It is necessary that

$$-1 < \text{erf}(z) < +1$$

otherwise an error message is printed.

Given

$$y = \text{erf}(z)$$

The argument z is

$$\xi = \delta \frac{1}{\sqrt{2}} \left[\xi - \frac{a_0 + \xi a_1 + \xi^2 a_2}{1 + \xi b_1 + \xi^2 b_2 + \xi^3 b_3} \right]$$

where

$$\delta = +1 \text{ for } y \text{ positive}$$

$$\delta = -1 \text{ for } y \text{ negative}$$

and

$$\xi = \left[-2 \ln \frac{1-|y|}{2} \right]^{1/2}$$

$$a_0 = 2.515517$$

$$a_1 = .802853$$

$$a_2 = .010328$$

$$b_1 = 1.432788$$

$$b_2 = .189269$$

$$b_3 = .001308$$

The error function is defined as

$$\text{erf}(z) = \frac{2}{\sqrt{\pi}} \int_0^z e^{-t^2} dt$$

SUBROUTINE RKAM

The purpose of this subroutine is to solve a set of N simultaneous, first order, ordinary differential equations of the form:

$$y_i' = f_i(x, y_1, y_2, \dots, y_n), i = 1, \dots, n$$

This subroutine operates in one of three modes:

1. Adams-Moulton variable step
2. Adams-Moulton fixed step
3. Runge-Kutta fixed step

Restrictions

1. No internal checks are made for over flow or under flow.
2. The user must provide an auxiliary subroutine which evaluates the first order derivatives. (See AUXSUB under Calling Sequence).
3. Initial conditions for both variables and derivatives must be stored in their respective locations prior to entering RKAM.

Usage

Calling Sequence:

CALL RKAM (XDP, HDP, VAR, DER, AUXSUB, N, OPT, EU, EL, HMAX, HMIN, ICNT, TEMPS, NH)

where

XDP	=	x, the independent variable in double precision.
HDP	=	h, the integration step-size in double precision.
VAR	=	N-dimensional vector of dependent variables (y , y , ...,y).
DER	=	N-dimensional vector of derivatives (y ', y ', ...,y ').
AUXSUB	=	Name of the auxiliary subroutine that computes derivatives and stores them in DER (1) to DER (N). The calling program must contain an external statement containing this name. Calling sequence must be CALL AUXSUB.
N	=	Number of equations.
OPT	=	Option indicator, zero for AM, non-zero for RK only.
EU	=	N-dimensional vector of upper bounds. (See Method).
EL	=	N-dimensional vector of lower bounds. (See Method).
HMAX	=	Absolute value of maximum allowable step-size.
HMIN	=	Absolute value of minimum allowable step-size. (HMIN>0).
ICNT	=	Internal counter - must be set to zero initially or when restarting.

TEMPS = A two-dimensional, (9,N), storage region. TEMP (1,I), I=1,...N must be set to zero initially or restarting. The least significant parts of the dependent variables are stored here.

NH = Index of the equation that caused halving when step-size has been reduced.

VAR, DER and all other locations referred to in both the main program and the auxiliary subroutine must be assigned in COMMON statements. If the step-size is changed outside of RKAM, the restart flag, ICNT, must be set to zero. This restriction does not apply in the "RK only" mode. HMAX, HMIN, EU and EL are also irrelevant in this mode.

The subroutine employs the fourth-order Adams-Moulton predictor-corrector method using the classical fourth-order Runge-Kutta method to obtain starting values. The user is referred to Hildebrand, Introduction to Numerical Analysis, pp. 199, 237, and 247 for theory and formulas.

AM has the following advantages with respect to RK:

1. Only half as many derivative evaluations per integration step are required to attain the same order of accuracy.
2. The local truncation error may be estimated at the conclusion of each integration step thereby providing a means for step-size control.

For each variable the local truncation error is approximately one-fourteenth the difference between the predicted and corrected values, that is

$$e_i = \frac{1}{14} |y_i^{(c)} - y_i^{(p)}|.$$

In RKAM, the difference $D_i = |y_i^{(c)} - y_i^{(p)}|$ are formed and compared with positive numbers EU_i and EL_i . If $D_i \geq E_i$ for any i , the step size is halved provided $|h/2| > -HMIN$. If $D_i < EL_i$ for all i and for three successive steps, the step size is doubled provided $|2h| \leq HMAX$. (Note that h may be held fixed either by setting $HMIN = HMAX$ or by making EU_i and EL_i prohibitively large and small respectively). If halving is called for during the first AM step following the three initial RK steps, the step-size is halved, the independent variable is set back to its initial value and the three RK steps are repeated. This will continue until the first AM step is successfully taken. From this point on halving is effected by interpolation of past data whereas doubling is accomplished by alternate selection of past data.

In selecting EU and EL , one should note the following:

1. The test is an absolute-test. To control relative error EU_i and EL_i should be computed as functions of y_i prior to each integration step.
2. Although the local truncation error in y_i is not allowed to exceed EU_i , this does not imply that the cumulative error will not exceed EU_i . Therefore, EU_i and EL_i should depend upon the maximum allowable cumulative error and the number of integration steps.

3. Since doubling h will multiply the truncation error by a factor of 2, EL_i should be chosen less than $EU_i/32$ if the advantages of doubling are not to be short-lived.

To control round-off, the independent variable is accumulated in double precision and the dependent variables are accumulated in partial double precision.

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3.0 INPUT DESCRIPTION

The input data is divided into two sets, 1) propellant properties data, and 2) case input data.

The propellant properties data contains all of the properties discussed in Section 1.2.1 that are necessary to run a given oxidizer/fuel combination. The appropriate propellant properties data set must be inserted into the input stream. A good deal of labor is required to prepare each such propellant properties data set. The data sets currently provided with the program are listed below.

<u>oxidizer/fuel</u>	<u>file name</u>	<u>(O/F)Stoic</u>	<u>state</u>	<u>pressure range</u>
air/JP4	JP4.DAT	14.46	gas/liquid	, P = 29.4 psi
LOX/GH2	O2H2.DAT	7.94	liquid/gas	, 200 ≤ P ≤ 400 psi
LOX/GH2	LOXH2.MID	7.94	liquid/gas	, 400 ≤ P ≤ 1500 psi
LOX/GH2	LOXH2.DAT	7.94	liquid/gas	, 1500 ≤ P ≤ 3500 psi
LOX/CH4	METHANE.MID	4.0	liquid/gas	, 500 ≤ P ≤ 1500 psi
LOX/C3H8	PROPAN.MID	3.63	liquid/gas	, 500 ≤ P ≤ 1500 psi
LOX/RP-1	RP1.DAT	3.40	liquid/liquid	, 200 ≤ P ≤ 350 psi
LOX/RP-1	F-1.RP1	3.40	liquid/liquid	, 500 ≤ P ≤ 1500 psi
NTO/N2H4	N2H4.DAT	1.44	liquid/liquid	, 100 ≤ P ≤ 1000 psi
NTO/A50	A50.DAT	2.25	liquid/liquid	, 100 ≤ P ≤ 1000 psi
NTO/MMH	MMH.DAT	2.50	liquid/liquid	, 50 ≤ P ≤ 3000 psi
NTO/UDMH	UDMH.DAT	3.06	liquid/liquid	, 100 ≤ P ≤ 1000 psi

Input specifications for preparing a propellant properties data set are presented in Section 3.1. Input required to execute a case is described in Section 3.2.

3.1 Propellant Properties Data Input

The propellant properties data consists of the drop liquid and vapor properties, and the properties of the combustion product gas. The \$INPUT namelist used to read tables defining these properties is given below. Listings for existing propellant property data sets are presented in Appendix A. LOX liquid and vapor properties are determined by curve fits rather than tables; see Appendix B. A formatted printout of the propellant data file is written to unit 89 whenever a case is run.

- \$INPUT = Namelist name read in Subroutine IN.
- NAMES(1) = Label used to identify the oxidizer and fuel e.g. NAMES(1) = 'LOX', 'RP-1'.
- FLAMEF = 0 - Burning drops see local mixture ratio
1 - Oxidizer controlled burning
2 - Fuel controlled burning
Default value is 0.
- TFLAME = Flame temperature ($^{\circ}\text{R}$) to be used for the oxidizer if FLAMEF=1, fuel if FLAMEF=2, above.
- PCRIT(1) = Critical pressure for oxidizer (psi).
- PCRIT(2) = Critical pressure for fuel (psi).
- NSP = The number of chemical species to be considered.
 $1 \leq \text{NSP} \leq 15$
- SPNAME(1) = The names of the chemical species, e.g., SPNAME(1) = 'H', 'H2', etc. (for print out only).
- WM(1) = Molecular weight of each chemical species.
- EPSI(1,1) = Interaction energy (ϵ_i/k) of each chemical species ($^{\circ}\text{K}$).
- SIGMA(1,1) = Molecular diameter, σ_i , of each chemical species (\AA Angstroms = 10^{-10} M).
- EPSOF(1) = Propellant molecular interaction energy ($^{\circ}\text{K}$).
EPSOF(1) = (ϵ_i/k) for oxidizer
EPSOF(2) = (ϵ_2/k) for fuel
- SIGOF(1) = Propellant molecular diameter (\AA Angstroms = 10^{-10} M).
SIGOF(1) = σ_{ox}
SIGOF(2) = σ_{fuel}

- WTMOL(1) = Propellant molecular weight.
 $WTMOL(1) = M_{w,ox}$
 $WTMOL(2) = M_{w,fuel}$
- NR = Number of mixture ratio, O/F, values for which properties are to be input.
 $1 \leq NR \leq 15$
- R(1) = Mixture ratio values, O/F.
- NPRES = Number of pressure values in PRSS(1).
- PRSS(1) = Up to three values of stagnation pressure (low, mid, and high) for which properties of the product gases have been prepared (psi).
- YSP(1,I,1) = Low pressure values. Mole fraction for each species, $I = 1,2,...NSP$ at each O/F.
- YSP(1,I,2) = Mid pressure values. Mole fraction for each species, $I = 1,2,...NSP$ at each O/F.
- YSP(1,I,3) = High pressure values. Mole fraction for each species, $I = 1,2,...NSP$ at each O/F.
- WMTAB(1,1) = Low pressure values. Gas molecular weight for each O/F.
- WMTAB(1,2) = Mid pressure values. Gas molecular weight for each O/F.
- WMTAB(1,3) = High pressure values. Gas molecular weight for each O/F.
- TC1(1,1) = Low pressure values. Gas stagnation temperature for each O/F ($^{\circ}R$).
- TC1(1,2) = Mid pressure values. Gas stagnation temperature for each O/F ($^{\circ}R$).
- TC1(1,3) = High pressure values. Gas stagnation temperature for each O/F ($^{\circ}R$).
- FGAMT(1) = γ value for each O/F at the mid range pressure.
- NT = Number of temperature values for which the species C_p and μ are to be input.
 $1 \leq NT \leq 15$
- TTAB(1) = Temperature values for the species C_p and μ ($^{\circ}R$).
- VSP(1,1) = μ_{ij} , viscosity ($\times 10^6$) at temperature i for species j (lbm/in-sec).
- CPTAB(1,1) = C_{pij} , specific heat at constant pressure at temperature i for species j (BTU/mole- $^{\circ}R$).

NTL(1)	=	The number of entries for the temperature of the liquid phase of the oxidizer, ≤ 15 .
NTL(2)	=	The number of entries for the temperature of the liquid phase of the fuel, ≤ 15 .
TLI(1,1)	=	$T_{L,ox}$; Liquid phase temperatures for the oxidizer ($^{\circ}R$).
TLI(1,2)	=	$T_{L,fuel}$; Liquid phase temperatures for the fuel ($^{\circ}R$).
PV(1,1)	=	$P_{vap,ox}$; vapor pressure for the ox, liquid phase, vs $T_{L,ox}$ (psi).
PV(1,2)	=	$P_{vap,fuel}$; vapor pressure for the fuel, liquid phase, vs $T_{L,fuel}$ (psi).
RHOL(1,1)	=	$\rho_{L,ox}$; density for the ox, liquid phase, vs $T_{L,ox}$ (lb/in ³). Note: (lb/in **3) = (g/cc) *.03616.
RHOL(1,2)	=	$\rho_{L,fuel}$; density for the fuel, liquid phase, vs $T_{L,fuel}$ (lb/in ³).
CP(1,1)	=	$C_{PL,ox}$; specific heat for the ox, liquid phase, vs $T_{L,ox}$ (BTU/lb- $^{\circ}R$).
CP(1,2)	=	$C_{PL,fuel}$; specific heat for the fuel, liquid phase, vs $T_{L,fuel}$ (BTU/lb- $^{\circ}R$).
LAM(1,1)	=	λ_{ox} ; heat of vaporization for the ox, vs $T_{L,ox}$ (BTU/lb).
LAM(1,2)	=	λ_{fuel} ; heat of vaporization for the fuel, vs $T_{L,fuel}$ (BTU/lb).
NTFLM(1)	=	Number of gas phase (vapor film) temperatures for oxidizer, ≤ 15 .
NTFLM(2)	=	Number of gas phase (vapor film) temperatures for fuel, ≤ 15 .
TFILM(1,1)	=	$T_{vap,ox}$; ox vapor film temperature ($^{\circ}R$).
TFILM(1,2)	=	$T_{vap,fuel}$; fuel vapor film temperature ($^{\circ}R$).
VVIS(1,1)	=	$\mu_{vap,ox} \times 10^6$; ox vapor viscosity (lbm/in-sec), vs $T_{vap,ox}$.
VVIS(1,2)	=	$\mu_{vap,fuel} \times 10^6$; fuel vapor viscosity (lbm/in-sec), vs $T_{vap,fuel}$.
KVAP(1,1)	=	$k_{vap,ox} \times 10^6$; ox vapor conductivity (BTU/in-sec- $^{\circ}R$), vs $T_{vap,ox}$.
KVAP(1,2)	=	$k_{vap,fuel} \times 10^6$; fuel vapor conductivity (BTU/in-sec- $^{\circ}R$), vs $T_{vap,fuel}$.
CPVAP(1,1)	=	$C_{p,vap,ox}$; ox vapor specific heat (BTU/lb- $^{\circ}R$), vs $T_{vap,ox}$.

CPVAP(1,2) = $C_{p,vap,fuel}$; fuel vapor specific heat (BTU/lb °R), vs $T_{vap,fuel}$.

VISL(15,2) = Liquid viscosity (lb/in) vs temp (°R).
(Required data for drop size predictions.)

STL(15,2) = Surface tension (lb/in) vs temp (°R).
(Required data for drop size predictions.)

\$END

3.2 Case Data Input, \$SCAP

The input is read using FORTRAN NAMELIST. Familiarity with this standard input procedure is assumed. All of the case data is input under the name \$SCAP as described below. Default values for the Namelist items are listed in parenthesis beside equal sign. The index (I) denotes drop type : I = 1 for oxidizer, I = 2 for fuel. The index (J) denotes drop group. Twenty, or less, drop groups are allowed for each propellant.

The nozzle geometry is input in \$DATA of the TDK computer program³.

\$SCAP

Propellant Properties File

FILENAME = ' ' Text defining the file name for the propellant properties; e.g.
FILENAME = 'F-1.RP1'.

Mixture Ratio Inputs

INDX = (0) INDX = 0: oxidizer and fuel system
INDX = 1: oxidizer system only
INDX = 2: fuel system only

EMDOT(I) = F_{ox} and F_{fuel} , the propellant feed rates (lbm/sec) oxidizer (I=1)
and fuel (I=2) $F_T = F_{ox} + F_{fuel}$.

RAT1 = (RATMX) Initial gas O/F ratio.

RATMN = Minimum O/F ratio.

RATMX = Maximum O/F ratio.

OFSTOC = Stoichiometric O/F ratio (not required input).

BRNMAX = Maximum burn rate parameter (used only to limit plotted values).

Flow Variables, Initial Values

P = Chamber pressure (psia).

U = Initial gas velocity (in/sec).

VI(I) = Droplet injection velocities (in/sec) oxidizer (I=1) and fuel (I=2).

TLL(I) = Droplet injection temperatures (°R) oxidizer (I=1) and fuel (I=2).

Flow Variables for the 2 D Option, Initial Values (see Section 1.2.9)

TWOD = (0) If TWOD=1, then the 2 D option will be used.

For the 2 D option the initial radial position, DIY, is required and the injection velocities VI(I) are replaced by VIX(J,I) and VIY(J,I).

DIY = (0.) Initial Radial Position of Drops (inches).

VIX(J,I) = (0,0) Initial Axial Jth Drop Velocity (in/sec).

VIY(J,I) = (0,0) Initial Radial Jth Drop Velocity (in/sec).

Dropsizes Prediction Variables

IDROP = Dropsizes calculation flag.
0 = input dropsizes
1 = calculate dropsizes (will override IPART)

DJ(I) = Injector diameters, (1) = OX, (2) = Fuel (inch).

ITYPE = Type of injector
1 - non-impinging
2 - like on like
3 - like on unlike

- 4 - O-F-O triplet
- 5 - F-O-F triplet
- 6 - like on like doublet
- 7 - shear/swirl coaxial

NEL(I) = Number of injector elements, (1) =OX, (2) = Fuel (inch).

If ITYPE = 7

DELP = Pressure drop of center spray in coaxial injector (psi).

FDJI = Annulus inner diameter for outer gas flow in coaxial injector (inch).

FDJO = Annulus outer diameter for outer gas flow in coaxial injector (inch).

Drop Distribution, Initial Values

IPART = (1) Flag for dropsize distribution.

If IPART = 1 log normal distribution of drop sizes is used. D, ND, ND1, and SIG, must be input.

D(I) = Initial mass median diameter, oxidizer (I=1) and fuel (I=2) drops (microns).

SIG(I) = Standard deviation for drop sizes, oxidizer and fuel drops.

ND(I) = (2*5) The total droplet mass is subdivided into ND groups of equal mass, oxidizer (I=1) and fuel (I=2).

ND1(I) = (2*1) The smallest ND(I) is further subdivided into ND1 groups of equal mass, resulting in a total of ND(I) + ND1(I) -1 groups. The total number of groups must be < 20 for the oxidizer, and < 20 for the fuel.

If IPART = 2 dropsize distributions are input using NSET(I) and DS (J,I).

NSET(I) = Number of drop groups, oxidizer (I=1) and fuel (I=2) (MAX=20).

DS(J,I) = Diameter of drop groups, J=1,2,...,NSET(I), oxidizer (I=1) and fuel (I=2) (microns).

Integration Control

X	= (0.)	Initial X value (inches).
XSTOP	= (100.)	Final X value (inches).
DX	= (.005)	Initial integration stepsize.
HMAX	= (.05)	Maximum integration stepsize.
HMIN	= (.0001)	Minimum integration stepsize.
EUR	= (.02)	Upper integration relative error limit.
ELR	= (.0006)	Lower integration relative error limit (set such that EUR/ELR>32).
OPT	= (0)	Integrator flag: = 0 for Adams Moulton = 1 for Runge-Kutta (fixed step, DX)

Print Plot Control

DXI(1)	= (1.0)	Print will occur between XI values at these intervals. XSTOP is always printed.
XI(1)	= (100.)	Values for control of print. From XI(1) to XI(2) Print every DXI(1) . . . From XI(N) to XI(N+1) Print every DXI(N)
PRINT1	= (F)	If true, additional print will be given for droplet radius, ΔV , and Reynolds nos.
PLTPROP	= (F)	If true, then plot input propellant properties (see Appendix B for an example)
IFPLOT	= (18*0)	Plot control for the Ith plot. The Ith plot will be output if IFPLOT (I) = 1
	<u>I</u>	<u>Ith variable</u>
	1	oxidizer/fuel ratio
	2	gas velocity
	3	oxidizer drop velocities vs distance

- 4 fuel drop velocities vs distance
- 5 oxidizer drop diameter vs distance
- 6 fuel drop diameter vs distance
- 7 oxidizer drop temperature vs distance
- 8 fuel drop temperature vs distance
- 9 fraction vaporized; ox. fuel, and total vs distance
- 10 vaporization rate; ox, fuel, and total vs distance
- 11 oxidizer drop velocities vs time
- 12 fuel drop velocities vs time
- 13 fraction vaporized; ox, fuel, & total vs time
- 14 vaporization rate; ox, fuel, & total vs time
- 15 oxidizer & fuel (2 plots) drop axial velocity vs radial velocity
(for use when TWOD=1)
- 16 oxidizer & fuel (2 plots) Drop Trajectories (for use when
TWOD=1)
- 17 burning rate parameter; ox, fuel and total (see Section 1.2.12)
- 18 vaporization curve fit plot set (see Section 1.2.13)

FAC1 = (1) Scale factor for plot.

if FAC1=1, then the plot will be normal size
if FAC1>1, then the plot will be enlarged by this amount, e.g. FAC1 = 1.1
for 10%
if FAC1<1, then the plot will be reduced by this amount

Curve-Fit data (see Section 1.2.13)

NFITS = (10) Number of curve-fit segments to be used in matching the
vaporization profile. NFITS≤10

ISTART = (1) If ISTART=0, then the curve fits will start at the x value where
a given amount of the injected liquid becomes vaporized. VAP
is input to specify this value of vapor fraction. This option can
be used with any system, i.e. liq-liq, liq-gas, or gas-liq.

If ISTART=1, then the curve fits will start at the x value where
a given gas phase O/F is reached, i.e. the input value OFEQ.
This option is intended for use with systems in which the
oxidizer vaporizes much faster than the fuel.

VAP = (.1) Vapor fraction at which curve fits start when ISTART=0 is
input.

OFEQ = (1.5)

Oxidant to fuel gas mixture ratio at which to start the vaporization curve fits (final equilibrium O/F) when ISTART=1 is input. (Set to zero to use core region model.)

\$END

4.0 INPUT AND OUTPUT FOR A SAMPLE CASE

The first sample case presented here is for a $\text{N}_2\text{O}_4/\text{N}_2\text{H}_4$ bipropellant engine operating at an overall mixture ratio of 1.16. The chamber pressure is 311 psia, and the nozzle throat diameter is 4 inches. This combustor has been shown experimentally to have a low vaporization efficiency.

The first page given here is a listing of the program case inputs; i.e., the TDK computer program³ \$DATA namelist, and the \$SCAP namelist input. This is followed by the printed and plotted output. This test case was run using the IBM RS6000/320H computer system. It required 420 seconds to execute, including the generation of plot files.

The second sample case is the same engine as described above, except that the fuel, N_2H_4 , has been replaced by monomethyl hydrazine (MMH). The mixture ratio has been increased to 1.6 (equal tank volume for ox and fuel) with the total propellant weight held constant. The effect this has on the engine operating conditions can be seen by comparing the plotted output obtained from the two cases.

The third sample case is for a TRW, Inc. 50K test engine which uses a pintle type injector (see discussion, Section 1.2.9). The propellants are LOX/RP-1. The 2D option (see Section 3.2) is used to analyze the combustion chamber performance. The spray has been approximated using cold flow data, and is assumed to consist of three streams. The first two streams contain both oxidizer and fuel, whereas the third stream contains only fuel. Each stream has a different initial direction, and a different drop size distribution. Input data, printed output, and plotted output are presented for this case. The plotted output includes calculated trajectories for the fuel and oxidizer drop groups.

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case1.dat

TITLE ICRPG 5th Conf., NTO/N2H4 DELT, INGEBO, JAN 69

DATA

\$DATA

SCAP=1,
RSI=1.992,
ECRAT=10.33,
RI=.01,
THETAI=32,
RWTU=.5,
ZT=6,
NZONES=1,

\$END

\$SCAP

FILENAME='N2H4.DAT'
DX = .001, HMAX = .001, HMIN = .0004,
RATMN=.2,
RATMX=8.,
BRNMAX=1.0,
OFSTOC=1.4,
EMDOT(1)=12.99, 11.24,
U=12.8,
P=311.,
VI(1)=648,1609,
TLL(1)=534.,534.,
D(1)=281.94,142.24,
SIG(1)=2.3,2.3,
ND=5,5,
ND1=5,5,
XI=6.0,
DXI=2.0,
PLTPROP=T,
IFPLOT=14*1,
FAC1=.9,

\$END

casel.out

TWO DIMENSIONAL KINETIC PROGRAM (TDK), LPP VERSION, MAY 1992

SOFTWARE AND ENGINEERING ASSOCIATES, INC.
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1
TITLE ICRPG 5th Conf., NTO/N2H4 DBLT, INGEBO, JAN 69

DATA

\$DATA

SCAP=1,
RSI=1.992,
ECRAT=10.33,
RI=.01,
THETA=32,
RWTU=.5,
ZT=6,
NZONES=1,
\$END
\$SCAP
FILENAME='N2H4.DAT'
DX = .001, HMAX = .001, HMIN = .0004,
RATMX=.2,
RATMY=.8,
BRNMAX=1.0,
OFSTOC=1.4,
EMDOT(1)=12.99, 11.24,
U=12.8,
P=311.,
VI(1)=648,1609,
TLL(1)=534.,534.,
D(1)=281.94,142.24,
SIG(1)=2.3,2.3,
ND=5,5,
ND1=5,5,
XI=6.0,
DKI=2.0,
PLTPROP=T,
IFPLOT=14*1,
FAC1=.9,
\$END

0TITLE ICRPG 5th Conf., NTO/N2H4 DBLT, INGEBO, JAN 69

ODATA

\$DATA

SCAP=1,
RSI=1.992,
ECRAT=10.33,

casel.out

```

RI=.01,
THETA1=32,
RWTU=.5,
ZT=6,
NZONES=1,
$END
$SCAP
FILENAME='N2H4.DAT'
DX = .001, HMAX = .001, HMIN = .0004,
RATMN=.2,
RATMX=8.,
BRNMAX=1.0,
OFSTOC=1.4,
EMDOT(1)=12.99, 11.24,
U=12.8,
P=311.,
VI(1)=648,1609,
TLL(1)=534.,534.,
D(1)=281.94,142.24,
SIG(1)=2.3,2.3,
ND=5,5,
ND1=5,5,
XI=6.0,
DXI=2.0,
PLTPROP=T,
IFPLOT=14*1,
FACI=.9,
$END
$INPUT
PCRIT=1470, 2131,
NAMES='NTO','N2H4',
NPRES= 3,
NSP= 9,
SPNAME= '      H','      H2','      H2O','      N2','      HO',
          '      O2','      H3N','      NO','      O',
WM(1)=    1.00,    2.00,    18.00,    28.00,    17.00,
          32.00,    17.00,    30.00,    16.00,
EPSI(1,1)= 37.000,    59.700,    809.000,    71.400,    79.800,
          106.700,    558.000,    116.700,    106.700,
SIGMA(1,1)= 2.7100,    2.8300,    2.6400,    3.8000,    3.1500,
          3.4700,    2.9000,    3.4900,    3.0500,
SIGOF= 3.9690,    4.0290,    WTMOL= 46.0000,    32.0000,
PRSS= 100.000,    300.000,    1000.000,    EPSOF= 331.900,    502.800,
NR= 9,
R(1)=    15.000,    10.000,    5.000,    2.000,    1.000,
          0.500,    0.200,    0.100,    0.066,
YSP(1, 1,1)=    0.0,    0.0,    0.0,    0.0070,    0.0200,
          0.0010,
YSP(1, 2,1)=    0.0,    0.0,    0.0,    0.0200,    0.1800,
          0.4080,    0.5600,    0.6120,    0.6310,
YSP(1, 3,1)=    0.1130,    0.1610,    0.2740,    0.4250,    0.3880,
          0.2190,    0.0900,    0.0460,    0.0300,
YSP(1, 4,1)=    0.3510,    0.3600,    0.3750,    0.3910,    0.3920,
          0.3690,    0.3480,    0.3400,    0.3390,
YSP(1, 5,1)=    0.0,    0.0,    0.0050,    0.0450,    0.0130,
YSP(1, 6,1)=    0.5330,    0.4790,    0.3380,    0.0790,    0.0020,
YSP(1, 8,1)=    0.0,    0.0,    0.0110,    0.0200,
YSP(1, 9,1)=    0.0,    0.0,    0.0,    0.0900,
YSP(1, 1,2)=    0.0,    0.0,    0.0,    0.0040,    0.0150,
YSP(1, 2,2)=    0.0,    0.0,    0.0,    0.0160,    0.1790,
          0.4100,    0.5600,    0.6120,    0.6280,
YSP(1, 3,2)=    0.1130,    0.1610,    0.2740,    0.4370,    0.3960,
          0.2190,    0.0900,    0.0450,    0.0300,
YSP(1, 4,2)=    0.3510,    0.3600,    0.3720,    0.3930,    0.3960,
          0.3960,    0.3480,    0.3410,    0.3370,
YSP(1, 5,2)=    0.0,    0.0,    0.0020,    0.0410,    0.0110,
YSP(1, 6,2)=    0.5330,    0.4790,    0.3380,    0.0780,
YSP(1, 7,2)=    0.0,    0.0,    0.0,    0.0,    0.0,
          0.0,    0.0,    0.0,    0.0020,
YSP(1, 8,2)=    0.0,    0.0,    0.0100,    0.0200,
YSP(1, 9,2)=    0.0,    0.0,    0.0,    0.0070,
YSP(1, 1,3)=    0.0,    0.0,    0.0,    0.0020,    0.0090,
YSP(1, 2,3)=    0.0,    0.0,    0.0,    0.0120,    0.1800,
          0.4110,    0.5590,    0.6090,    0.6260,
YSP(1, 3,3)=    0.1130,    0.1600,    0.2780,    0.4470,    0.4020,
          0.2200,    0.0900,    0.0450,    0.0300,
YSP(1, 4,3)=    0.3510,    0.3600,    0.3730,    0.3940,    0.3980,
          0.3700,    0.3470,    0.3400,    0.3370,
YSP(1, 5,3)=    0.0,    0.0,    0.0,    0.0370,    0.0070,
YSP(1, 6,3)=    0.5360,    0.4770,    0.3380,    0.0760,
YSP(1, 7,3)=    0.0,    0.0,    0.0,    0.0,    0.0,
          0.0,    0.0,    0.0030,    0.0050,
YSP(1, 8,3)=    0.0,    0.0,    0.0100,    0.0230,
YSP(1, 9,3)=    0.0,    0.0,    0.0,    0.0040,
WMTAB(1,1)= 29.0100,28.3200,26.5800,22.7400,18.7500,
          15.1300,12.5300,11.6200,11.3200,
WMTAB(1,2)= 29.0200,28.3200,26.5900,22.9000,18.8600,
          15.1400,12.5300,11.6300,11.3300,
WMTAB(1,3)= 29.0100,28.3200,26.6000,23.0500,18.9600,
          15.1400,12.5400,11.6600,11.3800,
TC1(1,1)= 1903.00,2533.00,3856.00,5290.00,5278.00,
          4018.00,2693.00,2156.00,1964.00,
TC1(1,2)= 1903.00,2533.00,3865.00,5429.00,5398.00,
          4025.00,2695.00,2158.00,1969.00,
TC1(1,3)= 1903.00,2532.00,3872.00,5558.00,5504.00,
          4014.00,2696.00,2165.00,1984.00,
FGAMT(1)=    1.310,    1.287,    1.253,    1.225,    1.232,
          1.268,    1.318,    1.344,    1.353,
NT= 6,
TTAB(1)= 540.00,1080.00,1980.00,3060.00,4860.00,7020.00,
VSP(1,1)= 0.4190, 0.6580, 0.9760, 1.2920, 1.7410, 2.2070,

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case1.out

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VSP(1,2)= 0.5000, 0.7920, 1.1790, 1.5640, 2.1080, 2.6720,
VSP(1,3)= 0.6140, 1.2030, 2.2020, 3.2520, 4.6930, 6.1210,
VSP(1,4)= 0.9950, 1.5980, 2.3670, 3.1460, 4.2420, 5.3780,
VSP(1,5)= 1.1020, 1.7810, 2.6400, 3.5110, 4.7370, 6.0040,
VSP(1,6)= 1.1560, 1.9120, 2.8630, 3.7960, 5.1300, 6.5060,
VSP(1,7)= 0.5830, 1.1730, 2.0620, 2.9320, 4.1090, 5.2830,
VSP(1,8)= 1.0750, 1.7950, 2.6970, 3.5710, 4.8330, 6.1300,
VSP(1,9)= 1.0560, 1.7470, 2.6160, 3.4680, 4.6870, 5.9440,
CPTAB(1,1)= 2.500, 2.500, 2.500, 2.500, 2.500, 2.500,
CPTAB(1,2)= 7.000, 7.050, 7.350, 7.990, 8.620, 9.110,
CPTAB(1,3)= 8.080, 8.730, 10.220, 11.750, 13.200, 14.010,
CPTAB(1,4)= 7.000, 7.240, 8.000, 8.510, 8.850, 8.990,
CPTAB(1,5)= 7.000, 7.040, 7.460, 8.090, 8.730, 9.100,
CPTAB(1,6)= 7.070, 7.700, 8.470, 8.890, 9.440, 9.920,
CPTAB(1,7)= 8.550, 10.720, 14.000, 16.530, 18.430, 19.350,
CPTAB(1,8)= 7.170, 7.500, 8.280, 8.690, 8.970, 9.120,
CPTAB(1,9)= 5.260, 5.090, 5.020, 5.010, 5.020, 5.120,
NTLM= 10, 13, NTFLM= 7, 6,
TLI(1,1)= 400.00, 440.00, 480.00, 520.00, 560.00, 600.00,
        640.00, 680.00, 720.00, 760.00,
TLI(1,2)= 400.00, 500.00, 550.00, 600.00, 650.00, 700.00,
        750.00, 800.00, 850.00, 900.00, 950.00, 1000.00, 1050.00,
FV(1,1)= 0.270, 0.850, 3.940, 11.800, 30.000, 80.000,
        180.000, 330.000, 660.000, 1200.00,
FV(1,2)= 0.001, 0.080, 0.480, 1.900, 6.000, 15.500,
        37.000, 75.000, 160.000, 250.000, 430.000, 660.000, 960.000,
RHOL(1,1)= .058000, .055600, .054100, .052700, .050850, .048700,
        .046300, .043500, .039350, .032400,
RHOL(1,2)= .038000, .036600, .035700, .034800, .033800, .032800,
        .031700, .030500, .029200, .028100, .027000, .026000, .025000,
CP(1,1)= 0.35000, 0.35000, 0.35300, 0.37200, 0.38800, 0.41400,
        0.46400, 0.54300, 0.70000, 0.87000,
CP(1,2)= .7014, .7295, .7435, .7575, .7716, .7856,
        .7997, .8137, .8277, .8418, .8558, .8698, .8839,
LAM(1,1)= 435.000, 430.000, 422.000, 412.000, 403.000, 392.000,
        379.000, 365.000, 346.000, 315.000,
LAM(1,2)= 606.52, 581.53, 569.95, 558.97, 548.60, 538.85,
        529.69, 521.14, 513.20, 505.86, 499.13, 493.02, 487.50,
TFILM(1,1)= 400.00, 600.00, 1000.00, 1600.00, 2400.00, 3200.00, 4000.00,
TFILM(1,2)= 400.00, 800.00, 1200.00, 2000.00, 2800.00, 4000.00,
VVIS(1,1)= 0.62400, 0.92000, 1.57000, 2.34000, 3.21000, 3.91000, 4.57000,
VVIS(1,2)= .4252, .8085, 1.1917, 1.9582, 2.7247, 3.8745,
KVAP(1,1)= 0.094, 0.224, 0.485, 0.875, 1.390, 1.910, 2.440,
KVAP(1,2)= 0.140, 0.300, 0.450, 0.950, 1.500, 2.400,
CPVAP(1,1)= 0.231, 0.238, 0.253, 0.269, 0.286, 0.297, 0.300,
CPVAP(1,2)= 0.320, 0.500, 0.610, 0.740, 0.820, 0.900,
$END

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STEADY-STATE SPRAY COMBUSTION MODEL

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0      MASS FLOW  RM      SIG  MOLE WT
O      12.99      .555E-02  2.30  46.00
F      11.24      .280E-02  2.30  32.00
1      ICRPG 5th Conf., NTO/W2H4 DBLT, INGEBO, JAN 69

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OX=-11.951 U= 12.8 T=5405. TO=5405. P= 311.00 PO= 311.00 O/F= .1160E+01 MACH= .000 AREA= 128.77 DADX= .000E+00
OVAPORIZED FRACTION O .004131 F .004116 BOTH .004124 COMB .003796 SOUND SPEED= .494E+05
VAPORIZATION RATE/IN O .015998 F .000530 BOTH .008859 COMB .014703

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	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
OXIDIZER DROPS									
1	51.0333	.21988E-09	647.	-.0128	539.98	.235E+10	.116E-03	-.125E+00	.00
2	77.2705	.76528E-09	648.	-.0128	537.00	.676E+09	.563E-04	-.585E-01	.00
3	97.0019	.15152E-08	648.	-.0128	536.07	.341E+09	.384E-04	-.394E-01	.00
4	114.6994	.25062E-08	648.	-.0128	535.57	.206E+09	.291E-04	-.296E-01	.00
5	131.5949	.37859E-08	648.	-.0128	535.26	.137E+09	.231E-04	-.235E-01	.00
6	182.2654	.10064E-07	648.	-.0128	534.74	.257E+09	.136E-04	-.137E-01	.00
7	281.9701	.37274E-07	648.	-.0129	534.37	.694E+08	.677E-05	-.680E-02	.00
8	436.2404	.13805E-06	648.	-.0129	534.18	.187E+08	.340E-05	-.340E-02	.00
9	819.9777	.91689E-06	648.	-.0129	534.07	.282E+07	.124E-05	-.127E-02	.00
OFUEL DROPS									
1	25.7360	.19523E-10	1605.	-.0322	541.96	.229E+11	.382E-05	-.414E-02	.00
2	38.9754	.67945E-10	1607.	-.0323	538.01	.659E+10	.184E-05	-.193E-02	.00
3	48.9311	.13453E-09	1608.	-.0323	536.76	.333E+10	.124E-05	-.130E-02	.00
4	57.8603	.22251E-09	1608.	-.0323	536.11	.201E+10	.936E-06	-.978E-03	.00
5	66.3847	.33612E-09	1608.	-.0323	535.69	.133E+10	.743E-06	-.777E-03	.00
6	91.9492	.89347E-09	1609.	-.0323	535.00	.251E+10	.435E-06	-.455E-03	.00
7	142.2518	.33092E-08	1609.	-.0323	534.50	.677E+09	.201E-06	-.225E-03	.00
8	220.0827	.12256E-07	1609.	-.0323	534.25	.183E+09	.145E-06	-.113E-03	.00
9	413.6806	.81401E-07	1609.	-.0323	534.09	.275E+08	.000E+00	-.421E-04	.00

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          OXIDIZER  FUEL  TOTAL  COMBUST.
BURNING RATE PARAMETER .005853 .000168 .006020 .009112
DRAG PARAMETER         2.36    2.03    4.39

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SCRIPT J .41877E-06
OINTEGRATION STEP= .0010
1      ICRPG 5th Conf., NTO/W2H4 DBLT, INGEBO, JAN 69

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OX= -9.952 U= 1033.6 T=5312. TO=5312. P= 311.04 PO= 311.13 O/F= .9682E+00 MACH= .021 AREA= 128.77 DADX= .000E+00
OVAPORIZED FRACTION O .296512 F .353920 BOTH .323143 COMB .272510 SOUND SPEED= .502E+05
VAPORIZATION RATE/IN O .122228 F .089880 BOTH .107665 COMB .112334

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	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
OXIDIZER DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	42.6872	.11241E-09	748.	.0057	655.30	.341E+09	.926E+00	-.211E+00	.00
4	72.9109	.56027E-09	681.	.0070	655.14	.206E+09	.776E+00	-.300E+00	.00
5	97.6494	.13461E-08	659.	.0075	655.06	.137E+09	.644E+00	-.309E+00	.00
6	162.7574	.32345E-08	645.	.0077	654.91	.257E+09	.381E+00	-.240E+00	.00
7	278.4055	.31215E-07	644.	.0078	654.68	.694E+08	.163E+00	-.136E+00	.00

casel.out

8	448.5818	.13106E-06	644.	.0078	652.29	.187E+08	.507E-01	-.662E-01	.00
9	839.4544	.91237E-06	645.	.0077	607.15	.282E+07	.493E-02	-.689E-02	.00
OFUEL DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	13.7477	.23831E-11	975.	.0012	872.50	.201E+10	.989E+00	-.104E+00	.00
5	36.6203	.45027E-10	936.	.0019	872.94	.133E+10	.866E+00	-.244E+00	.00
6	76.4360	.40937E-09	1157.	-.0025	873.19	.251E+10	.542E+00	-.195E+00	.00
7	141.8405	.26161E-08	1375.	-.0068	873.09	.677E+09	.209E+00	-.137E+00	.00
8	233.0443	.11849E-07	1462.	-.0085	846.11	.183E+09	.332E-01	-.485E-01	.00
9	424.6256	.81341E-07	1520.	-.0097	677.50	.275E+08	.743E-03	-.909E-03	.00

	OXIDIZER	FUEL	TOTAL	COMBUST.
BURNING RATE PARAMETER	.045318	.028835	.074154	.069622
DRAG PARAMETER	1.36	5.20	6.56	

SCRIPT J .41596E-06
 0 INTEGRATION STEP= .0010
 1 ICRPG 5th Conf., NTO/N2H4 DBLT, INGEBO, JAN 69

OX= -7.952 U= 1495.2 T=5406. TO=5406. P= 310.92 PO= 311.09 O/F= .1217E+01 MACH= .030 AREA= 128.77 DADX= .000E+00
 OVAPORIZED FRACTION O .498168 F .473134 BOTH .486555 COMB .457841 SOUND SPEED= .491E+05
 VAPORIZATION RATE/IN O .078892 F .050690 BOTH .066081 COMB .072505

	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
OXIDIZER DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	37.9557	.78928E-10	1155.	.0069	656.07	.137E+09	.979E+00	-.496E-01	.00
6	115.2832	.22126E-08	844.	.0132	655.75	.257E+09	.780E+00	-.139E+00	.00
7	242.4265	.20580E-07	725.	.0157	655.62	.694E+08	.448E+00	-.132E+00	.00
8	422.1899	.10871E-06	699.	.0162	655.55	.187E+08	.213E+00	-.828E-01	.00
9	845.1907	.87649E-06	679.	.0166	652.36	.282E+07	.441E-01	-.317E-01	.00
OFUEL DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
6	53.3299	.13887E-09	1287.	.0042	874.82	.251E+10	.845E+00	-.128E+00	.00
7	130.2188	.20217E-08	1358.	.0028	874.76	.677E+09	.389E+00	-.916E-01	.00
8	227.5801	.10813E-07	1447.	.0010	872.19	.183E+09	.118E+00	-.338E-01	.00
9	431.2100	.81122E-07	1513.	-.0004	751.48	.275E+08	.343E-02	-.105E-02	.00

	OXIDIZER	FUEL	TOTAL	COMBUST.
BURNING RATE PARAMETER	.028707	.015960	.044668	.044938
DRAG PARAMETER	.51	4.27	4.78	

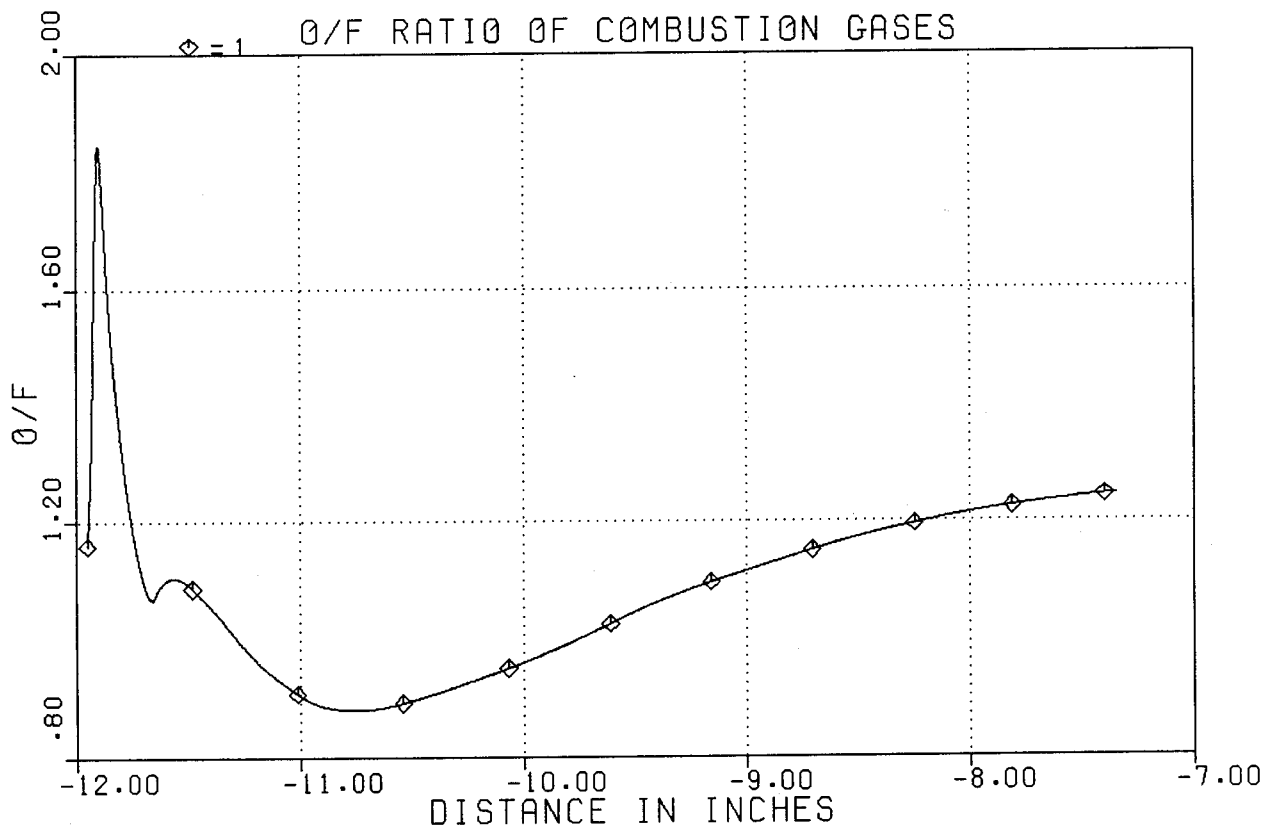
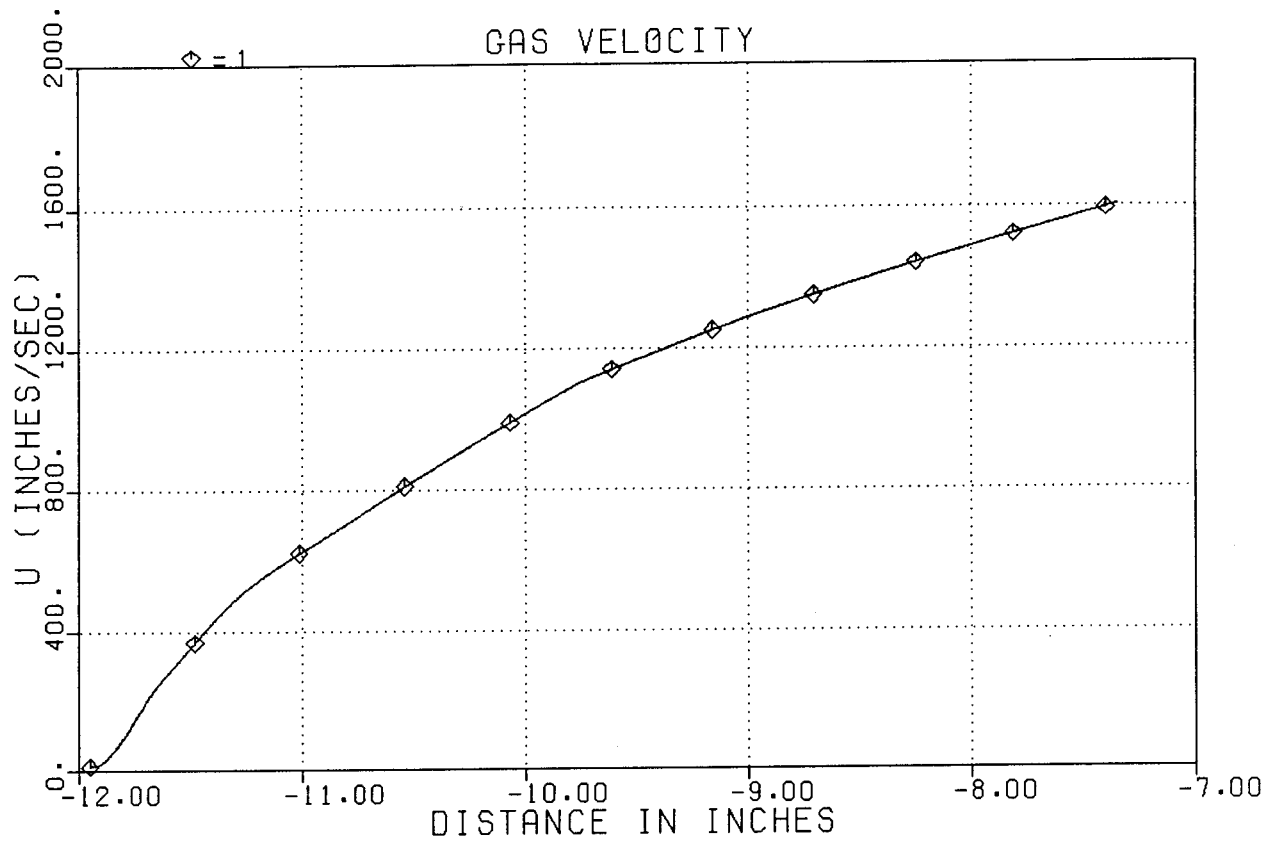
SCRIPT J .41752E-06
 0 INTEGRATION STEP= .0009
 1 ICRPG 5th Conf., NTO/N2H4 DBLT, INGEBO, JAN 69

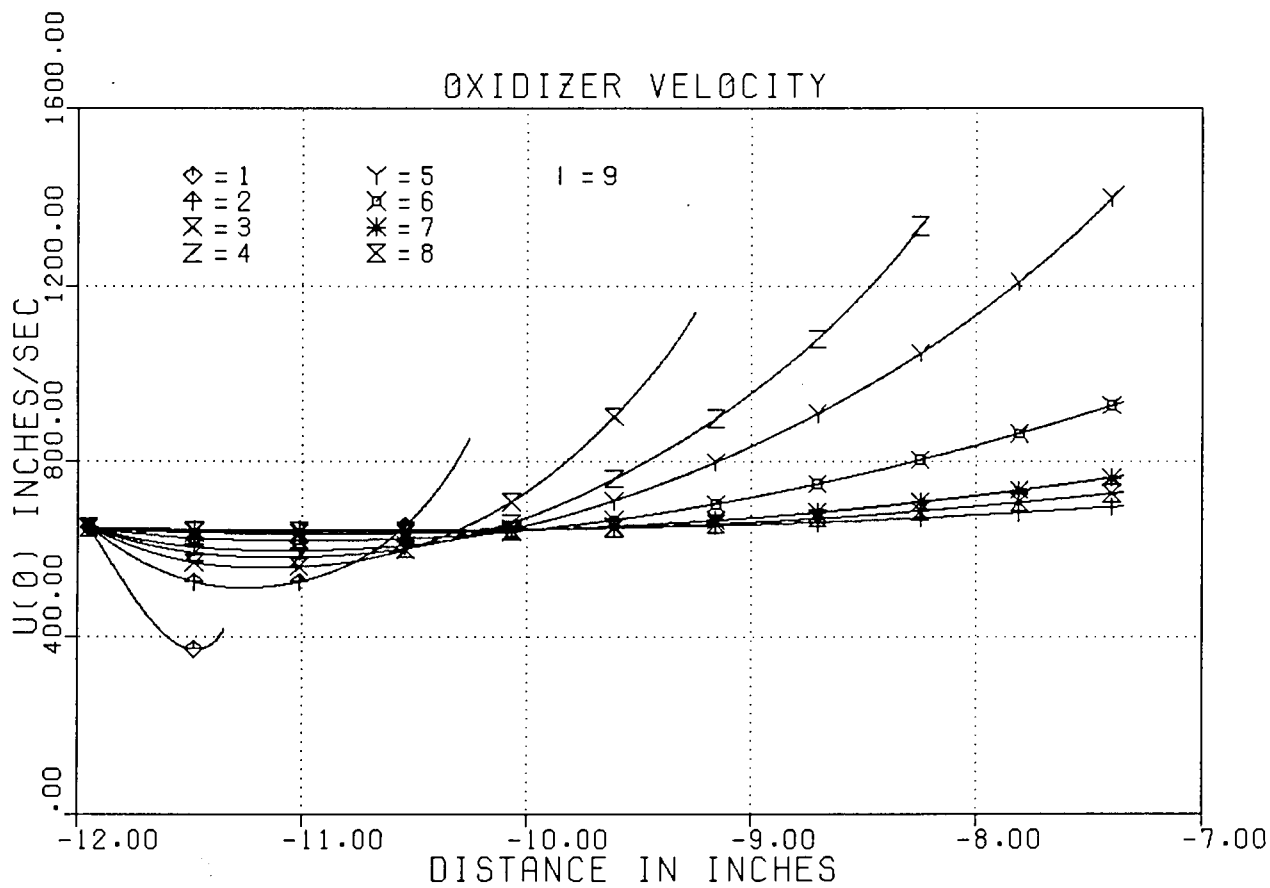
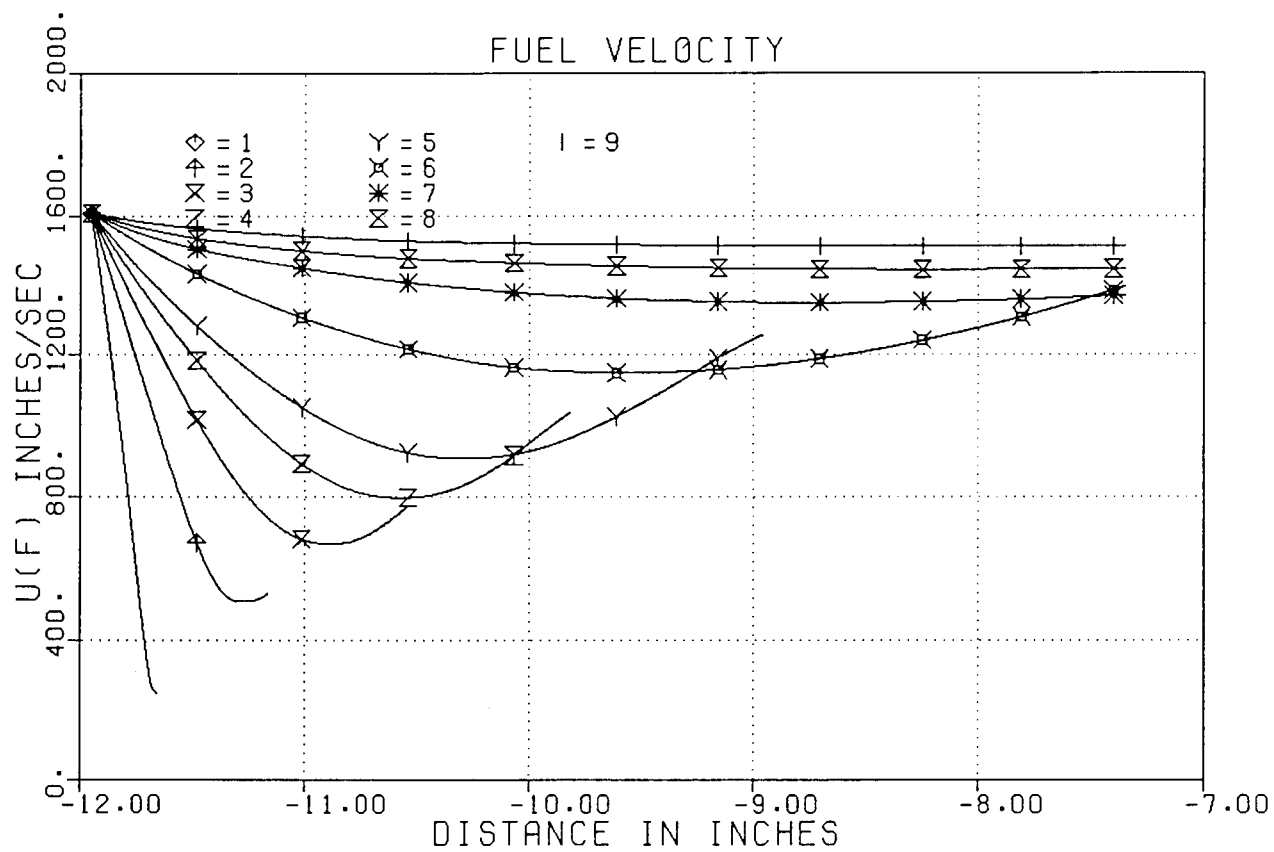
OX= -7.349 U= 1602.2 T=5407. TO=5407. P= 310.87 PO= 311.08 O/F= .1246E+01 MACH= .033 AREA= 128.77 DADX= .000E+00
 OVAPORIZED FRACTION O .542470 F .503292 BOTH .524296 COMB .498557 SOUND SPEED= .490E+05
 VAPORIZATION RATE/IN O .068269 F .048839 BOTH .059501 COMB .062743

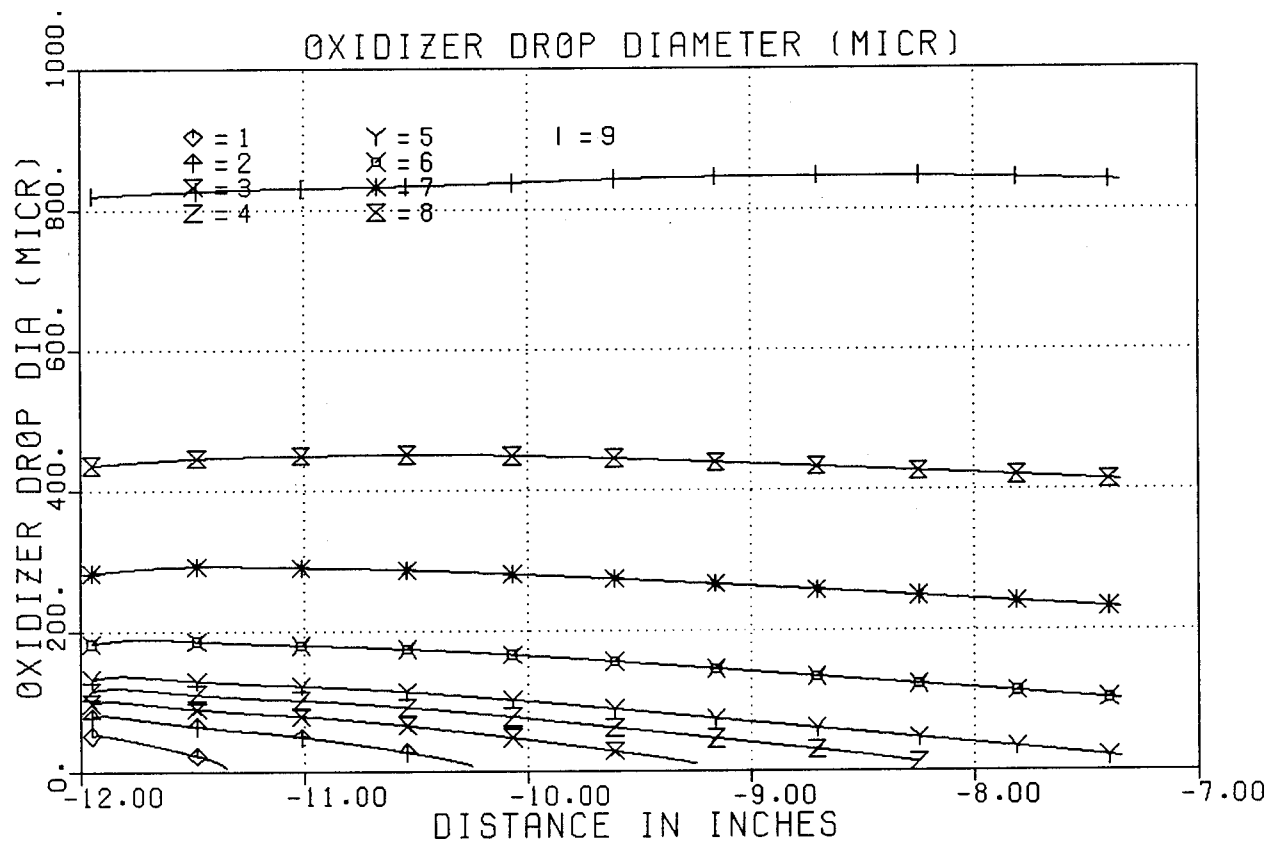
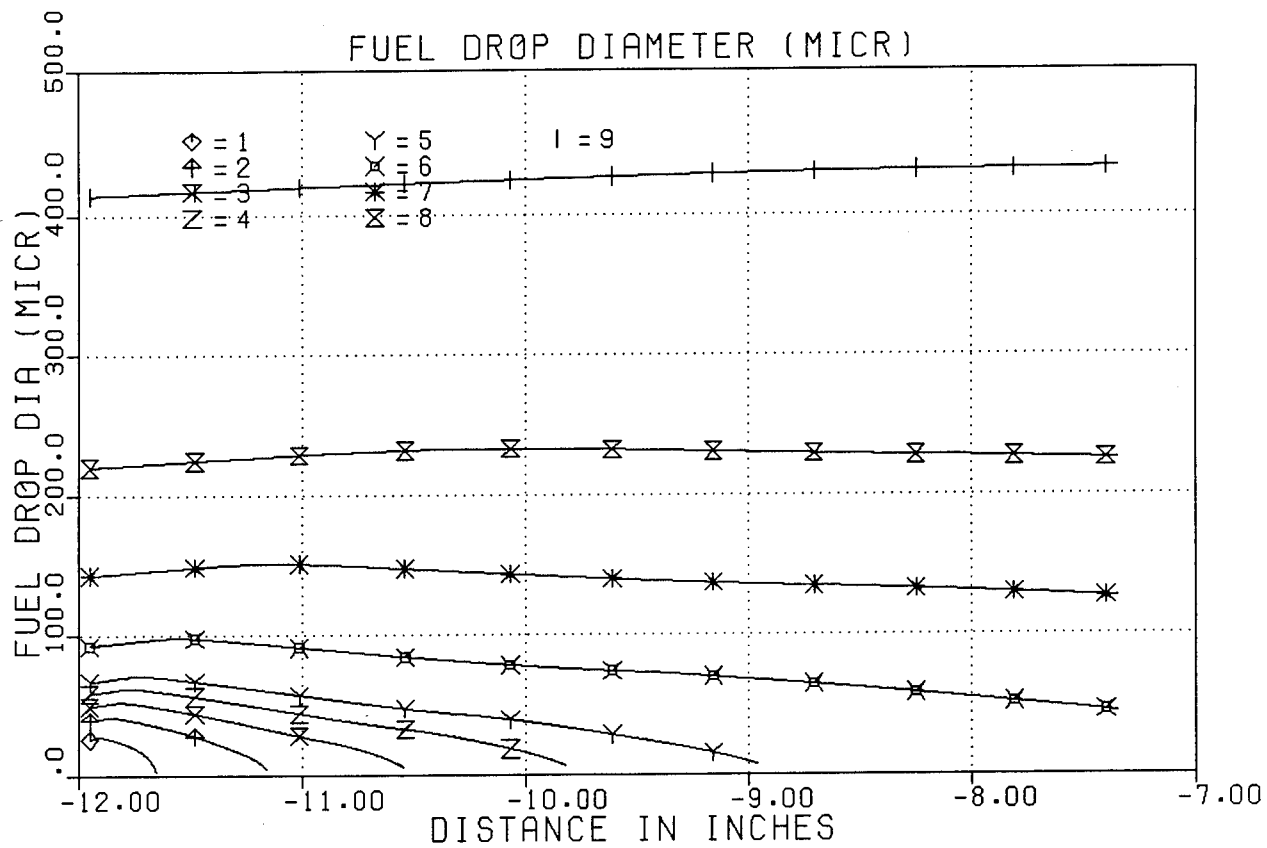
	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
OXIDIZER DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	18.7980	.95718E-11	1423.	.0037	657.17	.137E+09	.997E+00	-.148E-01	.00
6	100.7177	.14754E-08	938.	.0136	655.79	.257E+09	.853E+00	-.105E+00	.00
7	230.7054	.17736E-07	767.	.0171	655.65	.694E+08	.524E+00	-.121E+00	.00
8	413.2253	.10193E-06	730.	.0178	655.58	.187E+08	.262E+00	-.800E-01	.00
9	840.1609	.85809E-06	698.	.0185	654.51	.282E+07	.641E-01	-.344E-01	.00
OFUEL DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
6	44.2894	.79541E-10	1398.	.0042	874.79	.251E+10	.911E+00	-.923E-01	.00
7	125.9049	.18268E-08	1374.	.0047	875.15	.677E+09	.448E+00	-.102E+00	.00
8	225.4697	.10504E-07	1450.	.0031	873.65	.183E+09	.143E+00	-.486E-01	.00
9	432.2946	.81054E-07	1514.	.0018	762.48	.275E+08	.427E-02	-.210E-02	.00

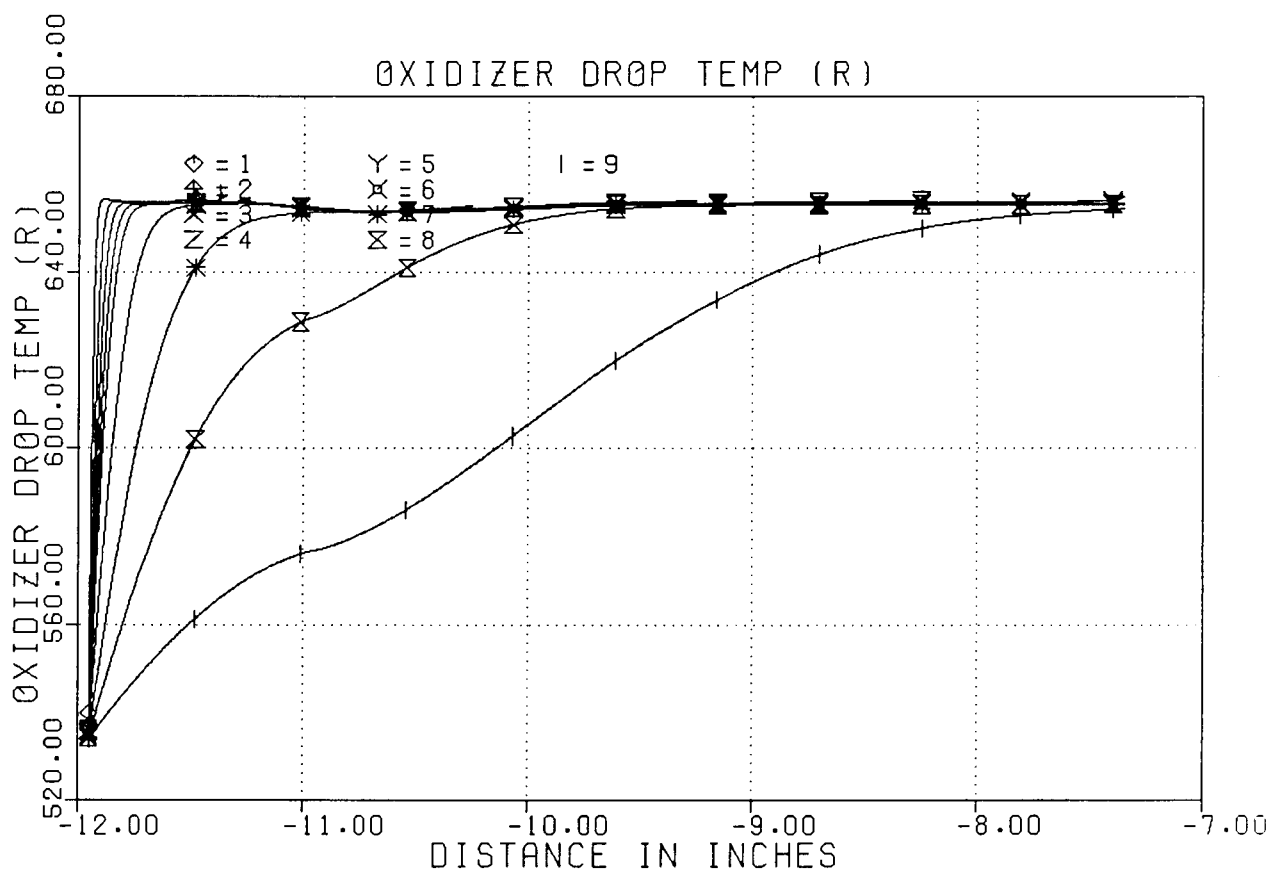
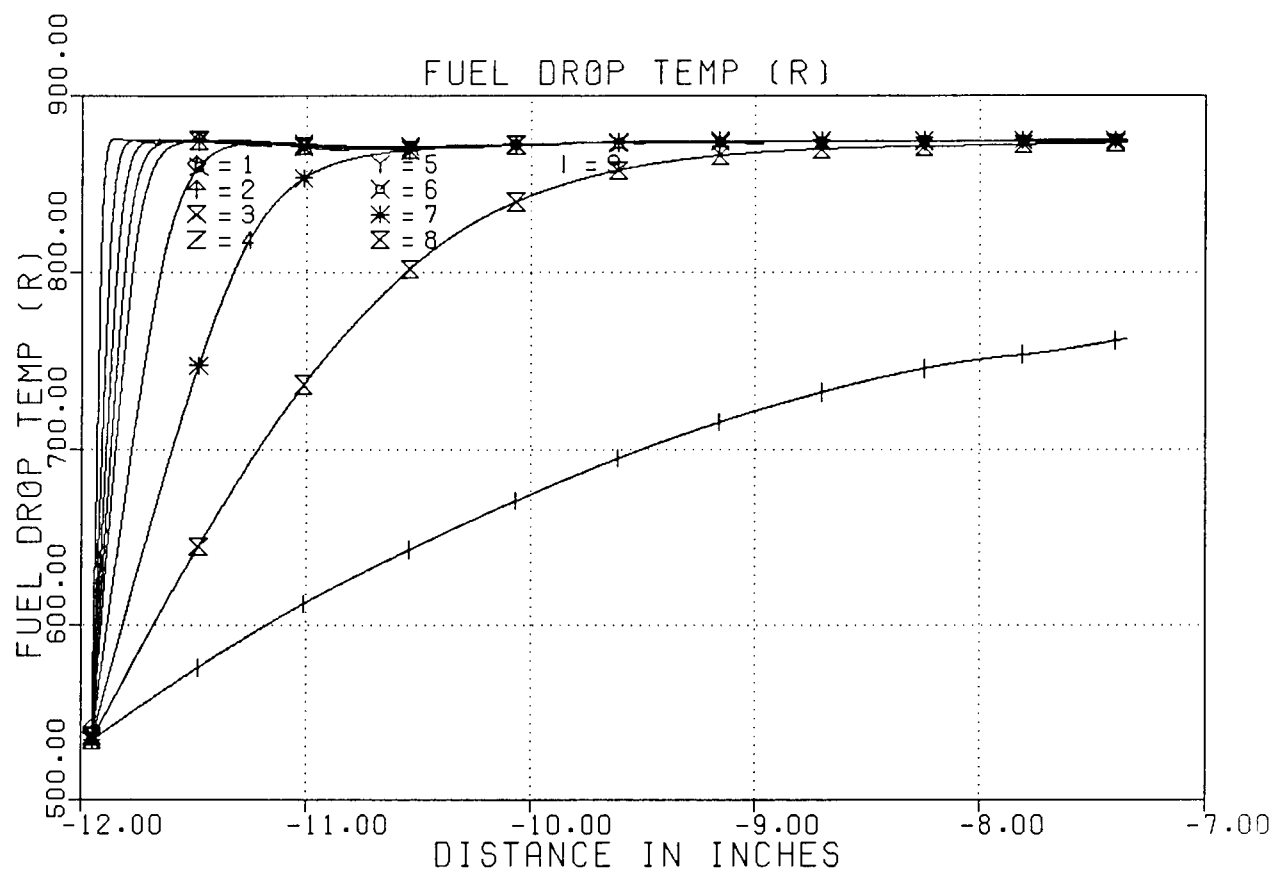
	OXIDIZER	FUEL	TOTAL	COMBUST.
BURNING RATE PARAMETER	.024776	.015337	.040113	.038887
DRAG PARAMETER	.44	2.16	2.60	

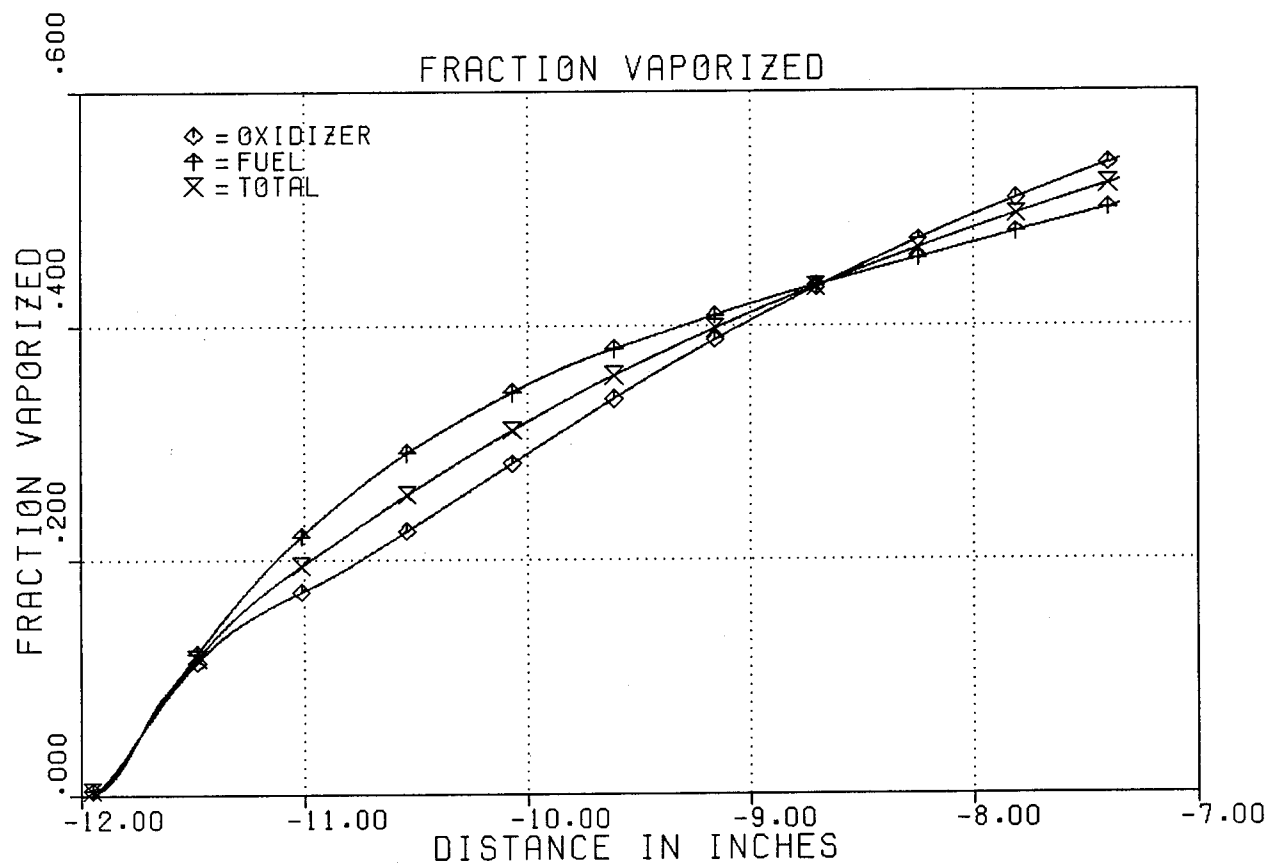
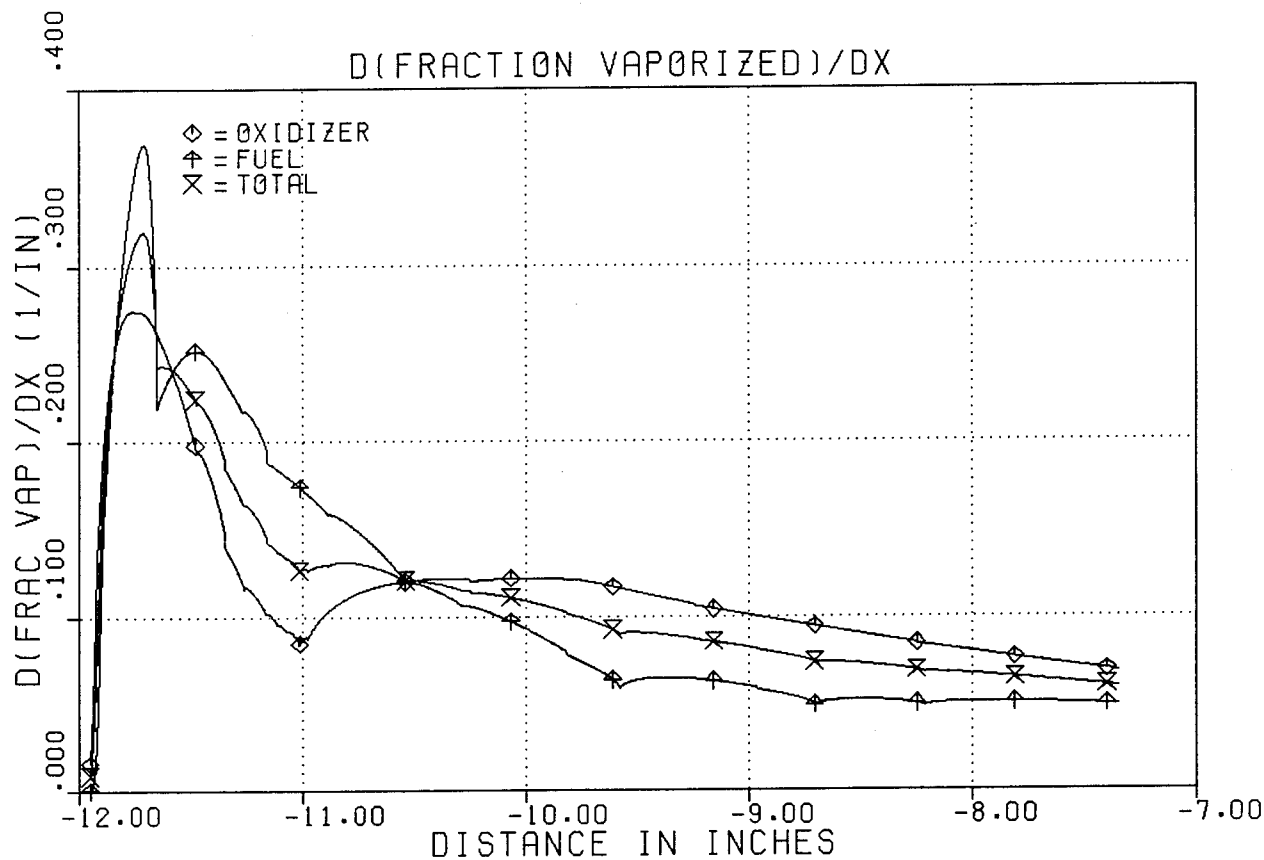
SCRIPT J .41690E-06
 0 INTEGRATION STEP= .0467
 DATA FOR ODE/ODK SAVED ON UNIT 15

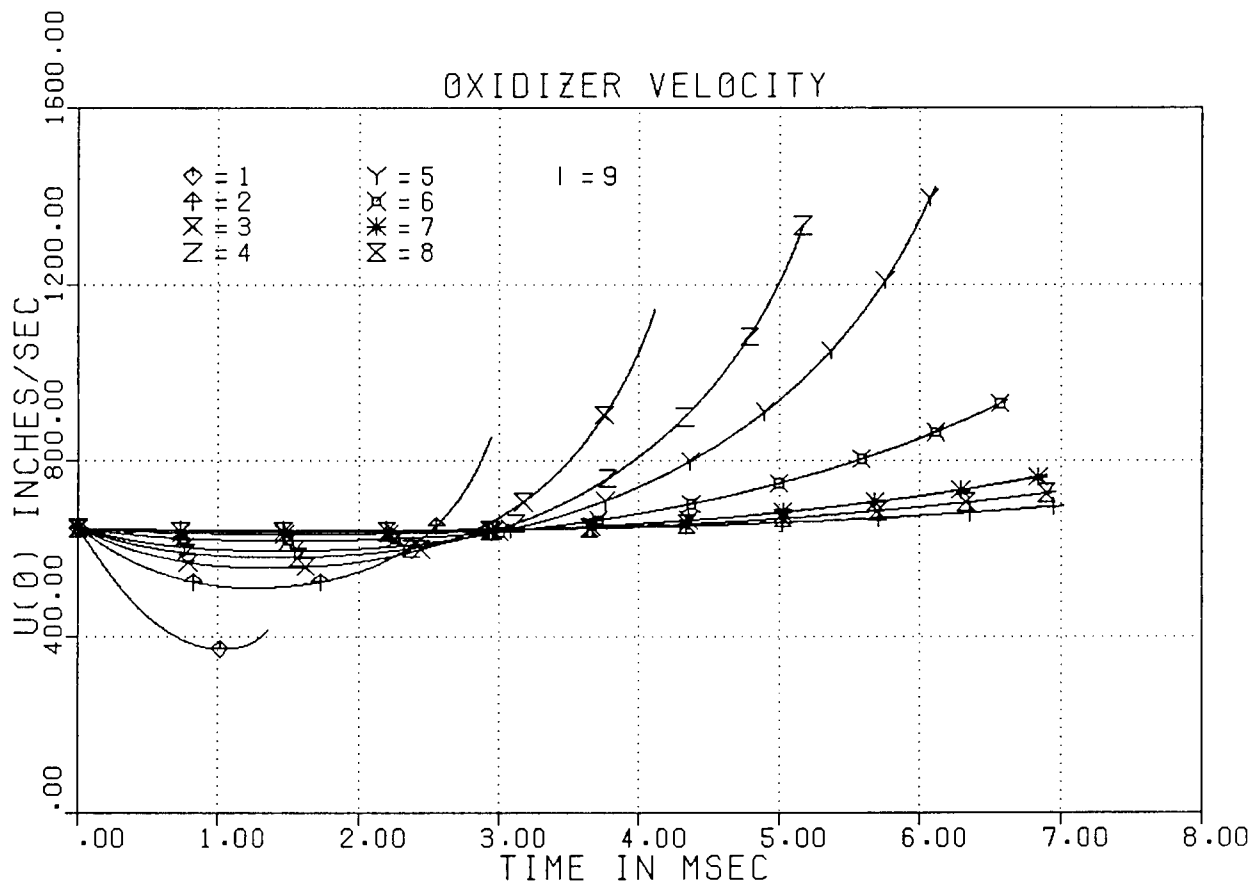
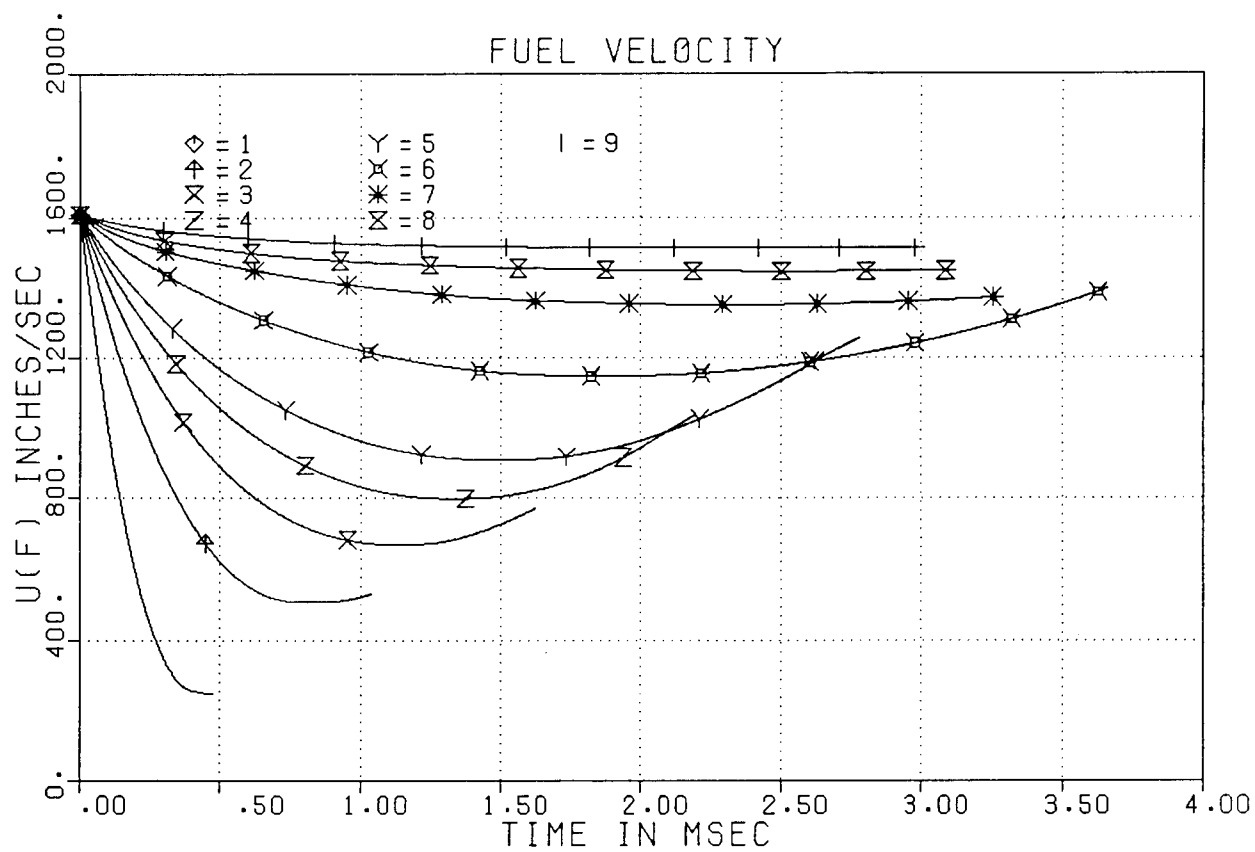


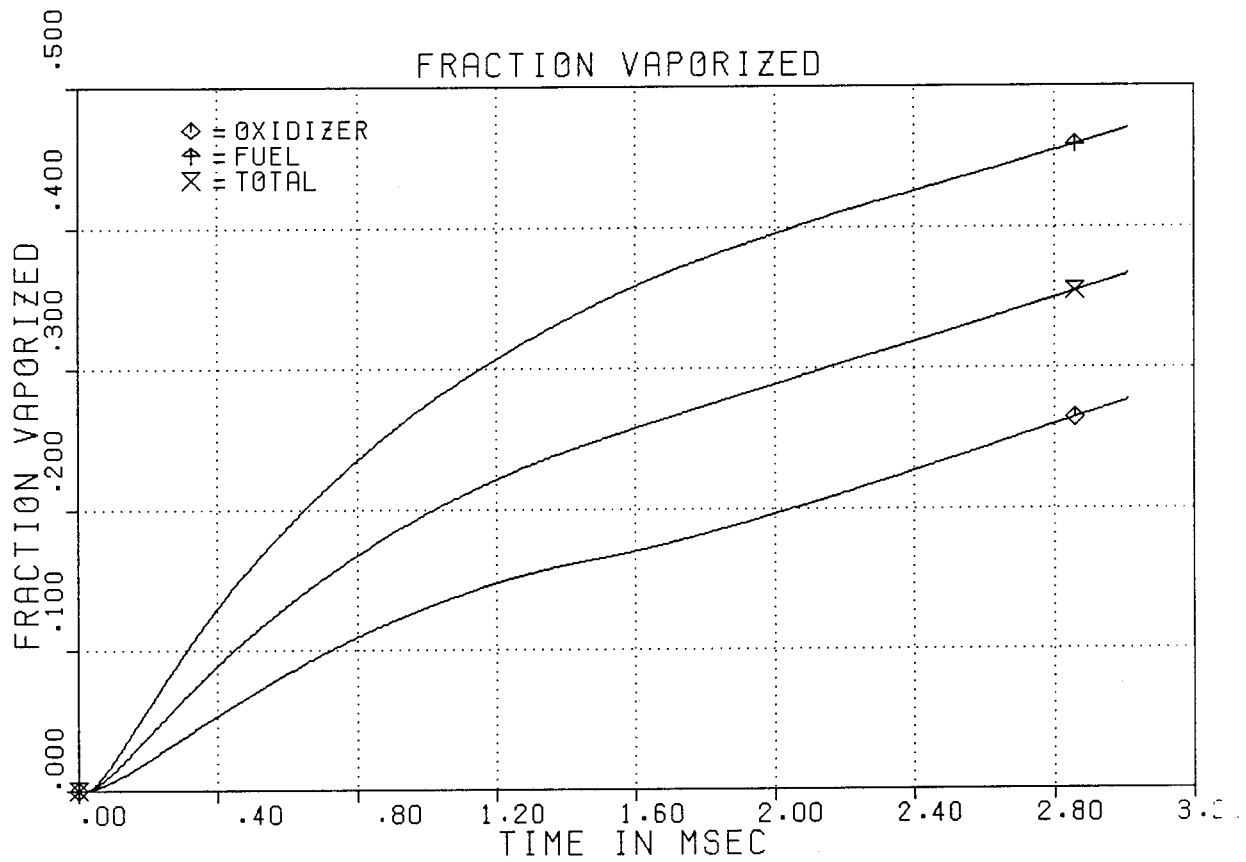
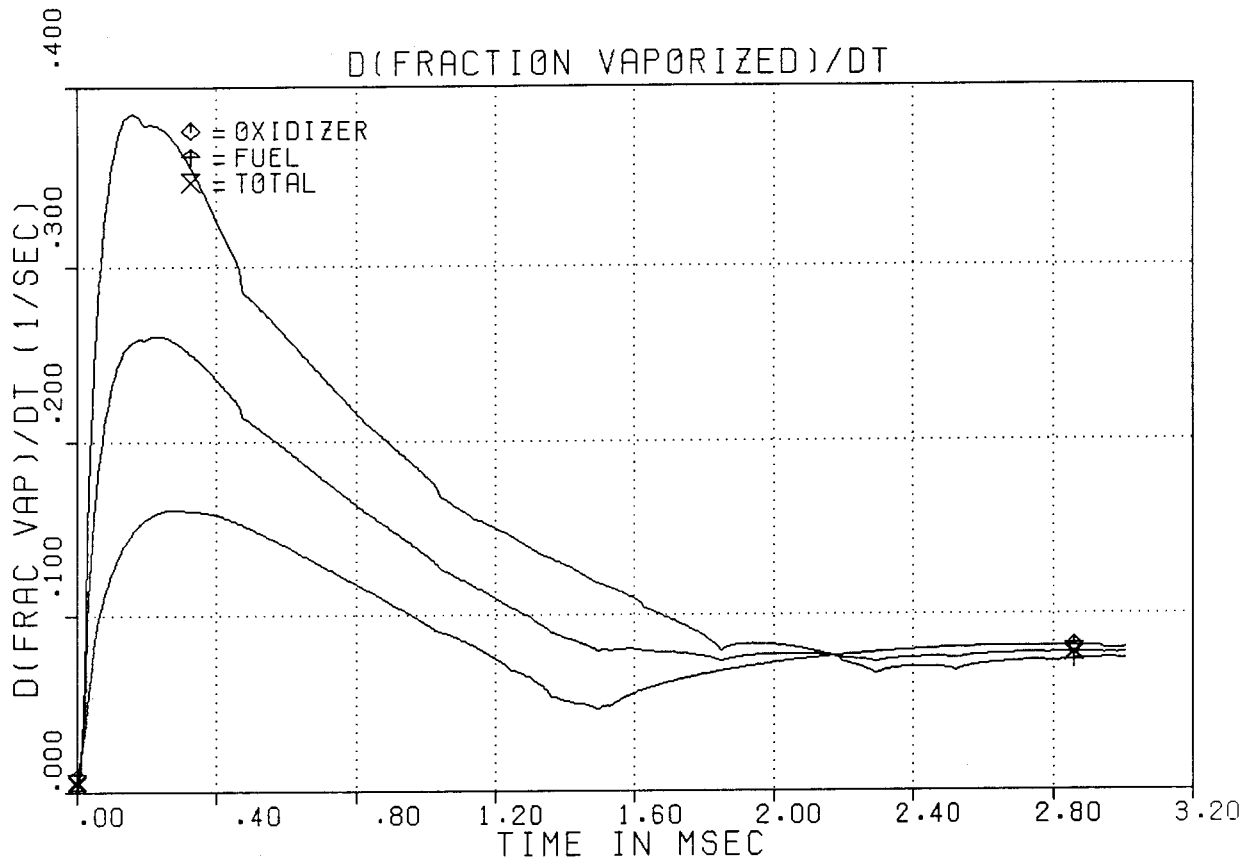












case2.dat

TITLE CASE2, NTO/MMH DBLT, INGEBO, JAN 69

DATA

\$DATA

SCAP=1,
RSI=1.992,
ECRAT=10.33,
RI=.01,
THETAI=32,
RWTU=.5,
ZT=6,
NZONES=1,

\$END

\$SCAP

FILENAME='MMH.DAT'
DX = .001, HMAX = .001, HMIN = .0004,
RATMN=.2,
RATMX=8.,
BRNMAX=1.0,
OFSTOC=1.4,
EMDOT=14.911, 9.319,
U=12.8,
P=311.,
VI(1)=648,1609,
TLL(1)=534.,534.,
D(1)=281.94,142.24,
SIG(1)=2.3,2.3,
ND=5,5,
ND1=5,5,
XI=6.0,
DXI=2.0,
PLTPROP=T,
IFPLOT=14*1,
FAC1=.9,
\$END

case2.out

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*****
TWO DIMENSIONAL KINETIC PROGRAM (TDK), LPP VERSION, MAY 1992

SOFTWARE AND ENGINEERING ASSOCIATES, INC.
1000 E WILLIAM STREET, SUITE 200, CARSON CITY NEVADA 89701
(702) 882 1966
EMAIL: UUNET!SEASERV!STU
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```

1
TITLE CASE2, NTO/MMH DBLT, INGEBO, JAN 69

DATA

\$DATA

```
SCAP=1,
RSI=1.992,
ECRAT=10.33,
RI=.01,
THETA=32,
RWTO=.5,
ZT=6,
NZONES=1,
$END
$SCAP
FILENAME='MMH.DAT'
DX = .001, HMAX = .001, HMIN = .0004,
RATMN=.2,
RATMX=.8,
BRNMAX=1.0,
OFSTOC= 2.500,
EMDOT=14.911, 9.319,
U=12.8,
P=311.,
VI(1)=648,1609,
TLL(1)=534.,534.,
D(1)=281.94,142.24,
SIG(1)=2.3,2.3,
ND=5,5,
ND1=5,5,
XI=6.0,
DKI=2.0,
PLTPROP=T,
IPFLOT=14*1,
FAC1=.9,
$END
```

OTITLE CASE2, NTO/MMH DBLT, INGEBO, JAN 69
ODATA

```
$DATA
SCAP=1,
RSI=1.992,
ECRAT=10.33,
```

case2.out

```

RI=.01,
THETA=32,
RWTU=.5,
ZT=6,
NZONES=1,
$END
$SCAP
FILENAME='MOH.DAT'
DX = .001, HMAX = .001, HMIN = .0004,
RATMX=.2,
RATMY=.8,
BRNMAX=1.0,
OFSTOC=1.4,
EMDOT=14.911, 9.319,
U=12.8,
P=311.,
VI(1)=648,1609,
TLL(1)=534.,534.,
D(1)=281.94,142.24,
SIG(1)=2.3,2.3,
ND=5,5,
ND1=5,5,
XI=6.0,
DXI=2.0,
PLTPROP=T,
IFFLOT=14*1,
FAC1=.9,
$END
$INPUT
PCRT=1470, 1195,
NAMES='N2O4', 'MOH',
NPRS= 3,
NSP=12,
SPNAME= '      H', '      H2', '      H2O', '      N2', '      CO', '      CO2',
          '      HO', '      O2', '      NO', '      O', '      CH4', '      H3N',
WM(1)= 1.00, 2.00, 18.00, 28.00, 28.00, 44.00, 17.00, 32.00, 30.00, 16.00, 16.00, 17.00,
EPSI(1,1)= 37.000, 59.700,809.000, 71.400, 91.700,195.000, 79.800,106.700,116.700,106.700,148.600,558.000,
SIGMA(1,1)= 2.7100, 2.8300, 2.6400, 3.8000, 3.6900, 3.9400, 3.1500, 3.4700, 3.4900, 3.0500, 3.7600, 2.9000,
SIGOF= 3.9690, 4.2460, WTMOL= 46.0000, 42.0000,
PRSS= 50.000, 500.000, 3000.000, EPSOF= 331.900, 467.400,
NR= 6,
R(1)= 0.500, 1.000, 1.500, 2.000, 2.300, 2.800,
YSP(1, 1,1)= 0.0, 0.0040, 0.0270, 0.0320, 0.0270, 0.0180,
YSP(1, 2,1)= 0.5630, 0.3740, 0.1960, 0.0950, 0.0640, 0.0370,
YSP(1, 3,1)= 0.0040, 0.1680, 0.2940, 0.3400, 0.3430, 0.3350,
YSP(1, 4,1)= 0.2400, 0.2720, 0.2970, 0.3100, 0.3140, 0.3190,
YSP(1, 5,1)= 0.1870, 0.1680, 0.1400, 0.1050, 0.0860, 0.0610,
YSP(1, 6,1)= 0.0010, 0.0130, 0.0300, 0.0520, 0.0630, 0.0760,
YSP(1, 7,1)= 0.0, 0.0, 0.0130, 0.0400, 0.0500, 0.0570,
YSP(1, 8,1)= 0.0, 0.0, 0.0010, 0.0120, 0.0280, 0.0630,
YSP(1, 9,1)= 0.0180,
YSP(1,10,1)= 0.0, 0.0, 0.0010, 0.0080, 0.0130, 0.0170,
YSP(1,11,1)= 0.0050,
YSP(1, 1,2)= 0.0, 0.0010, 0.0130, 0.0180, 0.0150, 0.0100,
YSP(1, 2,2)= 0.5370, 0.3750, 0.2000, 0.0880, 0.0550, 0.0280,
YSP(1, 3,2)= 0.0180, 0.1690, 0.3060, 0.3670, 0.3720, 0.3600,
YSP(1, 4,2)= 0.2470, 0.2730, 0.3010, 0.3160, 0.3200, 0.3240,
YSP(1, 5,2)= 0.1760, 0.1680, 0.1420, 0.1040, 0.0810, 0.0520,
YSP(1, 6,2)= 0.0030, 0.0130, 0.0300, 0.0560, 0.0710, 0.0870,
YSP(1, 7,2)= 0.0, 0.0, 0.0070, 0.0320, 0.0440, 0.0510,
YSP(1, 8,2)= 0.0, 0.0, 0.0, 0.0070, 0.0200, 0.0550,
YSP(1, 9,2)= 0.0, 0.0, 0.0010, 0.0080, 0.0140, 0.0220,
YSP(1,10,2)= 0.0, 0.0, 0.0, 0.0040, 0.0070, 0.0110,
YSP(1,11,2)= 0.0200,
YSP(1,12,2)= 0.0010,
YSP(1, 1,3)= 0.0, 0.0010, 0.0070, 0.0110, 0.0090, 0.0050,
YSP(1, 2,3)= 0.4950, 0.3760, 0.2010, 0.0820, 0.0460, 0.0210,
YSP(1, 3,3)= 0.0380, 0.1690, 0.3120, 0.3880, 0.3950, 0.3800,
YSP(1, 4,3)= 0.2580, 0.2730, 0.3030, 0.3210, 0.3260, 0.3280,
YSP(1, 5,3)= 0.1600, 0.1680, 0.1430, 0.1020, 0.0750, 0.0430,
YSP(1, 6,3)= 0.0040, 0.0130, 0.0300, 0.0610, 0.0800, 0.0100,
YSP(1, 7,3)= 0.0, 0.0, 0.0040, 0.0240, 0.0360, 0.0440,
YSP(1, 8,3)= 0.0, 0.0, 0.0, 0.0040, 0.0140, 0.0490,
YSP(1, 9,3)= 0.0250,
YSP(1,10,3)= 0.0, 0.0, 0.0020, 0.0040, 0.0070,
YSP(1,12,3)= 0.0020,
WMTAB(1,1)= 13.2800,16.7200,19.5800,21.6600,22.6100,23.8800,
WMTAB(1,2)= 13.6900,16.7400,19.8100,22.1100,23.1200,24.4000,
WMTAB(1,3)= 14.3000,16.7500,19.9200,22.4300,23.5200,24.8000,
TC1(1,1)= 2386.00,4224.00,5215.00,5513.00,5529.00,5463.00,
TC1(1,2)= 2569.00,4255.00,5456.00,5940.00,5983.00,5893.00,
TC1(1,3)= 2819.00,4265.00,5572.00,6239.00,6325.00,6435.00,
FOAMT(1)= 1.286, 1.264, 1.232, 1.223, 1.258, 1.320,
NT= 6,
TTAB(1)= 540.00,1080.00,1980.00,3060.00,4860.00,7020.00,
VSP(1,1)= 0.4190, 0.6580, 0.9760, 1.2920, 1.7140, 2.2070,
VSP(1,2)= 0.5000, 0.7950, 1.1790, 1.5640, 2.1080, 2.6720,
VSP(1,3)= 0.6140, 1.2030, 2.2020, 3.2520, 4.6930, 6.1210,
VSP(1,4)= 0.9950, 1.5980, 2.3670, 3.1460, 4.2420, 5.3780,
VSP(1,5)= 0.9940, 1.6230, 2.4160, 3.2090, 4.3320, 5.4930,
VSP(1,6)= 0.8510, 1.5200, 2.3500, 3.1490, 4.2450, 5.4020,
VSP(1,7)= 1.1020, 1.7810, 2.6400, 3.5110, 4.7370, 6.0040,
VSP(1,8)= 1.1560, 1.9120, 2.8630, 3.7960, 5.1300, 6.5060,
VSP(1,9)= 1.0750, 1.7950, 2.6970, 3.5710, 4.8330, 6.1300,
VSP(1,10)= 1.0560, 1.7470, 2.6160, 3.4680, 4.6870, 5.9440,
VSP(1,11)= 0.6280, 1.0780, 1.6370, 2.1770, 2.9420, 3.7350,
VSP(1,12)= 0.5830, 1.1730, 2.0620, 2.9320, 4.1090, 5.2830,
CPTAB(1,1)= 2.500, 2.500, 2.500, 2.500, 2.500, 2.500,
CPTAB(1,2)= 7.000, 7.050, 7.350, 7.990, 8.620, 9.110,
CPTAB(1,3)= 8.080, 8.730, 10.220, 11.750, 13.200, 14.010,
CPTAB(1,4)= 7.000, 7.240, 8.000, 8.510, 8.850, 8.990,

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case2.out

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CPTAB(1,5)= 7.000, 7.300, 8.100, 8.600, 8.910, 9.050,
CPTAB(1,6)= 8.940, 11.350, 13.290, 14.340, 14.830, 15.130,
CPTAB(1,7)= 7.000, 7.040, 7.460, 8.090, 8.730, 9.100,
CPTAB(1,8)= 7.070, 7.700, 8.470, 8.890, 9.440, 9.920,
CPTAB(1,9)= 7.170, 7.500, 8.280, 8.690, 8.970, 9.120,
CPTAB(1,10)= 5.260, 5.090, 5.020, 5.010, 5.020, 5.120,
CPTAB(1,11)= 8.570, 12.560, 18.150, 21.700, 24.000, 25.000,
CPTAB(1,12)= 8.550, 10.720, 14.000, 16.530, 18.430, 19.350,
NTL= 10, 12, NTFILM= 7, 6,
TLI(1,1)= 400.00, 440.00, 480.00, 520.00, 560.00, 600.00, 640.00, 680.00, 720.00, 760.00,
TLI(1,2)= 500.00, 550.00, 600.00, 650.00, 700.00, 750.00, 800.00, 850.00, 900.00, 950.00, 1000.00, 1050.00,
FV(1,1)= 0.270, 0.850, 3.940, 11.800, 30.000, 80.000, 180.000, 330.000, 660.000, 1200.00,
FV(1,2)= 0.280, 1.420, 4.930, 13.300, 29.700, 57.900, 101.500, 164.000, 248.000, 357.000, 491.000, 651.000,
RHOL(1,1)= .058000, .055600, .054100, .052700, .050850, .048700, .046300, .043500, .039350, .032400,
RHOL(1,2)= .032100, .031100, .030300, .029200, .028200, .027400, .026400, .024900, .023500, .021700, .019500, .016200,
CP(1,1)= 0.35000, 0.35000, 0.35300, 0.37200, 0.38800, 0.41400, 0.46400, 0.54300, 0.70000, 0.87000,
CP(1,2)= 0.69500, 0.70100, 0.70700, 0.71300, 0.72100, 0.73100, 0.74000, 0.75000, 0.76100, 0.77500, 0.79000, 0.80500,
LAM(1,1)= 435.000, 430.000, 422.000, 412.000, 403.000, 392.000, 379.000, 365.000, 346.000, 315.000,
LAM(1,2)= 402.000, 368.000, 343.000, 324.000, 309.000, 296.000, 286.000, 275.000, 260.000, 235.000, 210.000, 170.000,
TFILM(1,1)= 400.00, 600.00, 1000.00, 1600.00, 2400.00, 3200.00, 4000.00,
TFILM(1,2)= 400.00, 800.00, 1200.00, 2000.00, 2800.00, 4000.00,
VVIS(1,1)= 0.62400, 0.92000, 1.57000, 2.34000, 3.21000, 3.91000, 4.57000,
VVIS(1,2)= 0.33400, 0.58400, 0.84400, 1.33000, 1.75000, 2.25000,
KVAP(1,1)= 0.094, 0.224, 0.485, 0.875, 1.390, 1.910, 2.440,
KVAP(1,2)= 0.100, 0.310, 0.584, 1.180, 1.620, 2.050,
CFVAP(1,1)= 0.231, 0.238, 0.253, 0.269, 0.286, 0.297, 0.300,
CFVAP(1,2)= 0.450, 0.560, 0.655, 0.798, 0.853, 0.876,
SEND

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STEADY-STATE SPRAY COMBUSTION MODEL

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0 MASS FLOW RM SIG MOLE WT
O 14.91 .555E-02 2.30 46.00
F 9.32 .280E-02 2.30 42.00
1 CASE2, NTO/MMH DBLT, INGEBO, JAN 69

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OX=-11.951 U= 12.8 T=5440. TO=5440. P= 311.00 PO= 311.00 O/F= .1605E+01 MACH= .000 AREA= 128.77 DADX= .000E+00
OVAPORIZED FRACTION O .004246 F .004233 BOTH .004241 COMB .003908 SOUND SPEED= .487E+05
VAPORIZATION RATE/IN O .015954 F .002245 BOTH .010727 COMB .002072

```

	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
OXIDIZER DROPS									
1	51.0309	.21988E-09	647.	-.0130	539.82	.270E+10	.116E-03	-.124E+00	.00
2	77.2687	.76528E-09	648.	-.0130	536.93	.776E+09	.562E-04	-.583E-01	.00
3	97.0004	.15152E-08	648.	-.0130	536.01	.392E+09	.383E-04	-.393E-01	.00
4	114.6981	.25062E-08	648.	-.0130	535.53	.237E+09	.290E-04	-.296E-01	.00
5	131.5936	.37859E-08	648.	-.0130	535.23	.157E+09	.231E-04	-.235E-01	.00
6	182.2643	.10064E-07	648.	-.0130	534.72	.295E+09	.136E-04	-.137E-01	.00
7	281.9694	.37274E-07	648.	-.0130	534.36	.797E+08	.677E-05	-.679E-02	.00
8	436.2399	.13805E-06	648.	-.0130	534.18	.215E+08	.340E-05	-.340E-02	.00
9	819.9772	.91689E-06	648.	-.0130	534.07	.324E+07	.124E-05	-.126E-02	.00
OFUEL DROPS									
1	25.7531	.17045E-10	1604.	-.0326	543.37	.218E+11	.162E-04	-.177E-01	.00
2	38.9883	.59320E-10	1607.	-.0327	538.72	.626E+10	.784E-05	-.819E-02	.00
3	48.9423	.11745E-09	1608.	-.0327	537.26	.316E+10	.532E-05	-.550E-02	.00
4	57.8704	.19426E-09	1608.	-.0327	536.48	.191E+10	.400E-05	-.413E-02	.00
5	66.3939	.29345E-09	1608.	-.0327	535.99	.126E+10	.322E-05	-.328E-02	.00
6	91.9568	.78006E-09	1609.	-.0327	535.18	.238E+10	.192E-05	-.192E-02	.00
7	142.2577	.28891E-08	1609.	-.0327	534.59	.642E+09	.922E-06	-.948E-03	.00
8	220.0872	.10701E-07	1609.	-.0327	534.30	.173E+09	.498E-06	-.475E-03	.00
9	413.6838	.71069E-07	1609.	-.0327	534.11	.261E+08	.200E-06	-.178E-03	.00

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OXIDIZER FUEL TOTAL COMBUST.
BURNING RATE PARAMETER .006611 .000581 .007192 .001284
DRAG PARAMETER 2.65 1.89 4.54

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SCRIPT J .41125E-06
0 INTEGRATION STEP= .0010
1 CASE2, NTO/MMH DBLT, INGEBO, JAN 69

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OX=-9.952 U= 858.3 T=3981. TO=3981. P= 311.07 PO= 311.14 O/F= .9255E+00 MACH= .018 AREA= 128.77 DADX= .000E+00
OVAPORIZED FRACTION O .244041 F .421929 BOTH .312458 COMB .257454 SOUND SPEED= .472E+05
VAPORIZATION RATE/IN O .095830 F .103938 BOTH .099369 COMB .101097

```

	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
OXIDIZER DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	20.4689	.12565E-10	729.	.0027	646.35	.776E+09	.984E-00	-.107E+00	.00
3	59.5828	.31006E-09	627.	.0049	646.05	.392E+09	.795E-00	-.281E+00	.00
4	86.0369	.93370E-09	617.	.0051	645.95	.237E+09	.627E-00	-.284E+00	.00
5	108.6266	.18794E-08	618.	.0051	645.88	.157E+09	.504E-00	-.255E+00	.00
6	170.2275	.72346E-08	628.	.0049	645.70	.295E+09	.281E-00	-.170E+00	.00
7	282.8682	.33210E-07	637.	.0047	645.41	.797E+08	.109E-00	-.891E-01	.00
8	448.0984	.13410E-06	640.	.0046	634.24	.215E+08	.284E-01	-.331E-01	.00
9	832.9667	.91385E-06	643.	.0046	585.35	.324E+07	.332E-02	-.336E-02	.00
OFUEL DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
6	63.9665	.20541E-09	1054.	-.0041	862.07	.238E+10	.737E+00	-.248E+00	.00
7	136.9595	.20163E-08	1310.	-.0096	862.03	.642E+09	.302E+00	-.203E+00	.00
8	230.8168	.10100E-07	1399.	-.0115	823.12	.173E+09	.541E-01	-.682E-01	.00
9	425.3890	.70891E-07	1477.	-.0131	668.86	.261E+08	.250E-02	-.281E-02	.00

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OXIDIZER FUEL TOTAL COMBUST.
BURNING RATE PARAMETER .037441 .025379 .062820 .062658
DRAG PARAMETER 2.13 1.70 3.83

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SCRIPT J .30134E-06
0 INTEGRATION STEP= .0010

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case2.out

1

CASE2, NTO/MMH DBLT, INGEBO, JAN 69

OX= -7.952 U= 1419.8 T=4831. TO=4832. P= 310.91 PO= 311.08 O/F= .1265E+01 MACH= .029 AREA= 128.77 DADK= .000E+00
 OVAPORIZED FRACTION O .435276 F .550596 BOTR .479629 COMB .459200 SOUND SPEED= .485E+05
 VAPORIZATION RATE/IN O .085808 F .040534 BOTR .068686 COMB .090524

	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
OXIDIZER DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	31.2232	.44224E-10	1116.	.0063	651.85	.237E+09	.982E+00	-.524E-01	.00
5	60.3349	.31921E-09	937.	.0099	651.64	.157E+09	.916E+00	-.112E+00	.00
6	132.7128	.33981E-08	762.	.0136	651.44	.295E+09	.662E+00	-.171E+00	.00
7	255.7076	.24315E-07	698.	.0149	651.22	.797E+08	.348E+00	-.131E+00	.00
8	431.9399	.11727E-06	682.	.0152	650.83	.215E+08	.151E+00	-.763E-01	.00
9	844.3793	.89471E-06	668.	.0155	636.46	.324E+07	.242E-01	-.200E-01	.00
OFUEL DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
6	16.8210	.37019E-11	1342.	.0016	869.90	.238E+10	.995E+00	-.332E-01	.00
7	117.8508	.12726E-08	1275.	.0030	870.26	.642E+09	.560E+00	-.122E+00	.00
8	223.8920	.87886E-08	1375.	.0009	864.00	.173E+09	.179E+00	-.450E-01	.00
9	431.1303	.70360E-07	1463.	-.0009	745.05	.261E+08	.997E-02	-.301E-02	.00

	OXIDIZER	FUEL	TOTAL	COMBUST.
BURNING RATE PARAMETER	.035011	.010336	.045347	.056105
DRAG PARAMETER	.71	2.89	3.60	

SCRIPT J .36866E-06

OINTEGRATION STEP= .0004

1

CASE2, NTO/MMH DBLT, INGEBO, JAN 69

OX= -7.349 U= 1553.9 T=5016. TO=5016. P= 310.86 PO= 311.06 O/F= .1348E+01 MACH= .032 AREA= 128.77 DADK= .000E+00
 OVAPORIZED FRACTION O .484368 F .574956 BOTR .519208 COMB .510989 SOUND SPEED= .487E+05
 VAPORIZATION RATE/IN O .076548 F .042676 BOTR .063791 COMB .080756

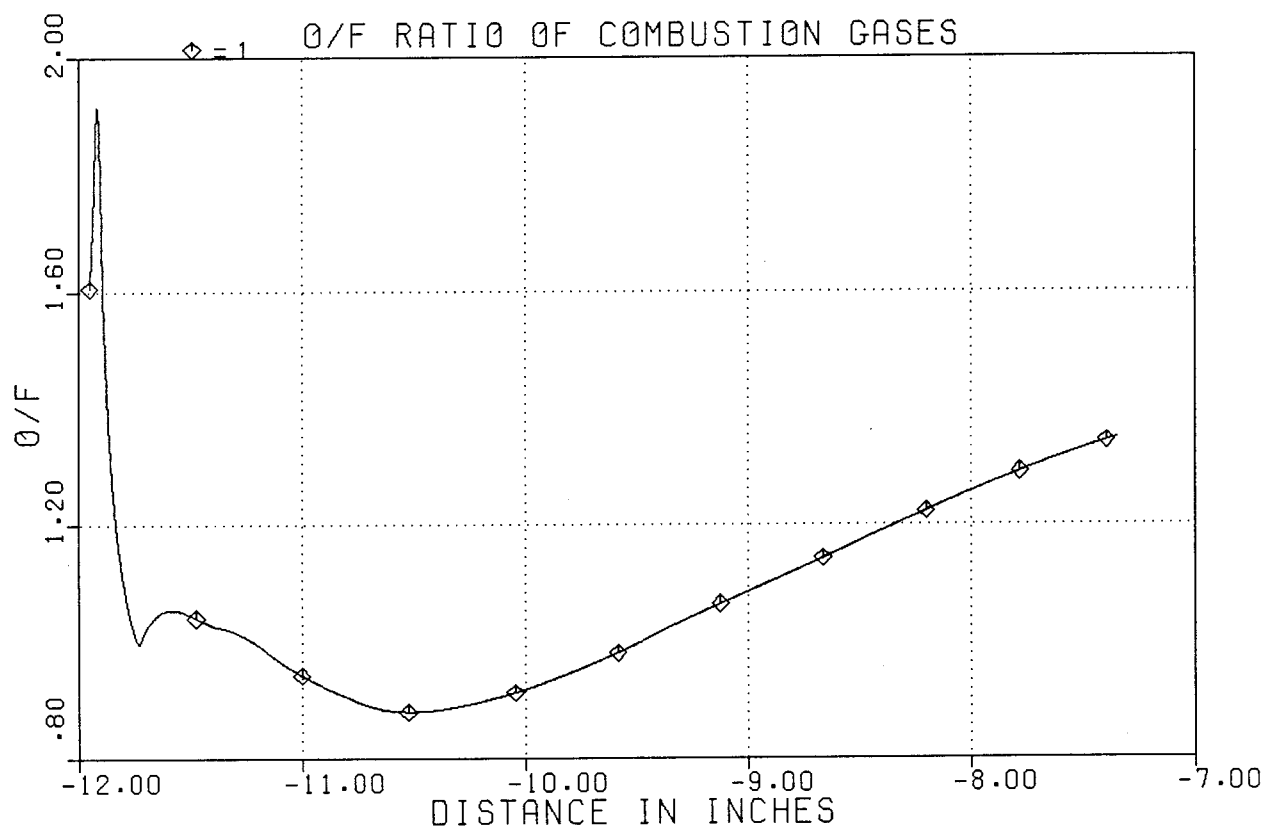
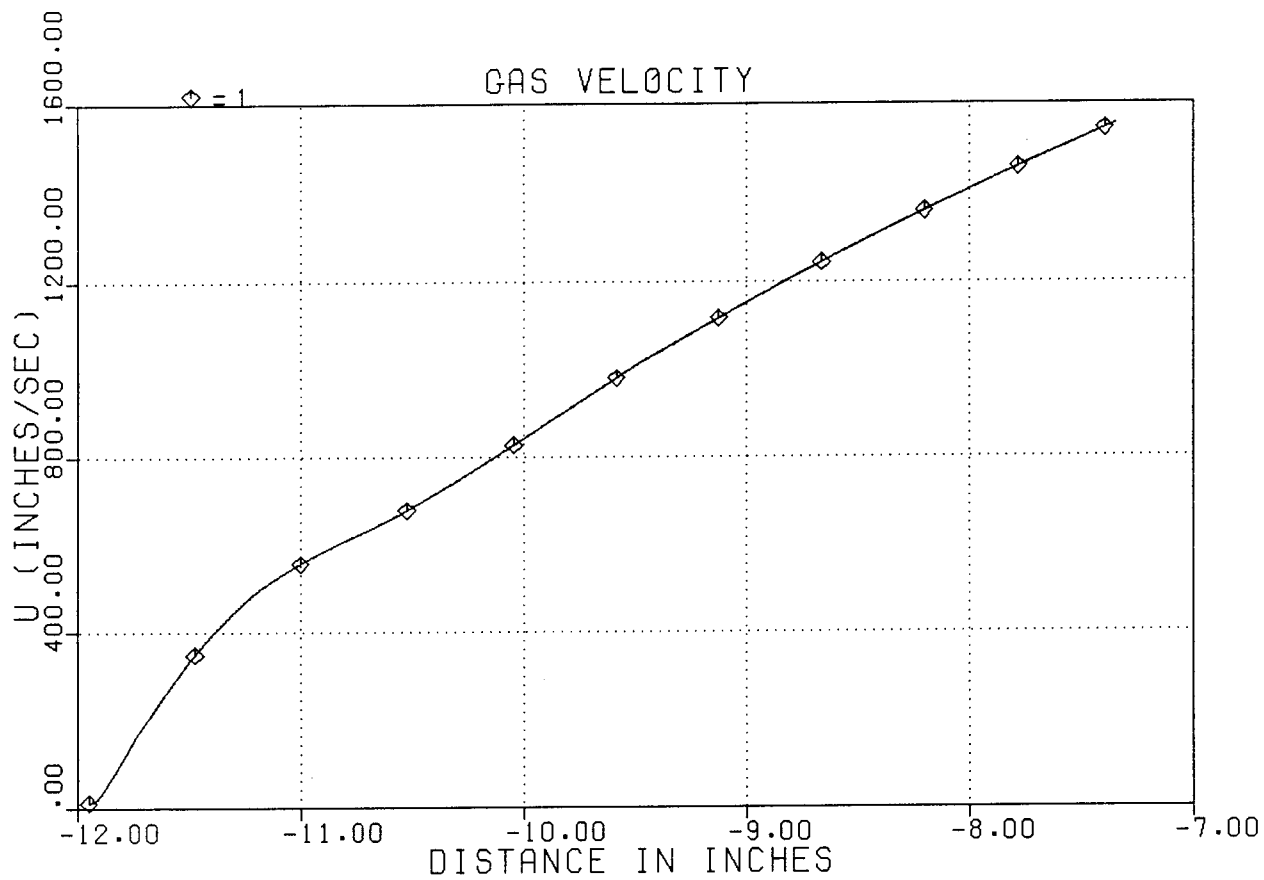
	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
OXIDIZER DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	44.0640	.12414E-09	1127.	.0088	652.67	.157E+09	.967E+00	-.605E-01	.00
6	119.0551	.24489E-08	838.	.0147	652.59	.295E+09	.757E+00	-.141E+00	.00
7	245.2727	.21419E-07	737.	.0168	652.41	.797E+08	.425E+00	-.126E+00	.00
8	424.1742	.11083E-06	710.	.0173	652.14	.215E+08	.197E+00	-.779E-01	.00
9	843.9910	.88184E-06	686.	.0178	645.61	.324E+07	.382E-01	-.267E-01	.00
OFUEL DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
6	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
7	110.4312	.10432E-08	1301.	.0052	873.44	.642E+09	.639E+00	-.137E+00	.00
8	220.9319	.83992E-08	1379.	.0036	868.71	.173E+09	.215E+00	-.728E-01	.00
9	431.9287	.70233E-07	1463.	.0019	756.12	.261E+08	.118E-01	-.448E-02	.00

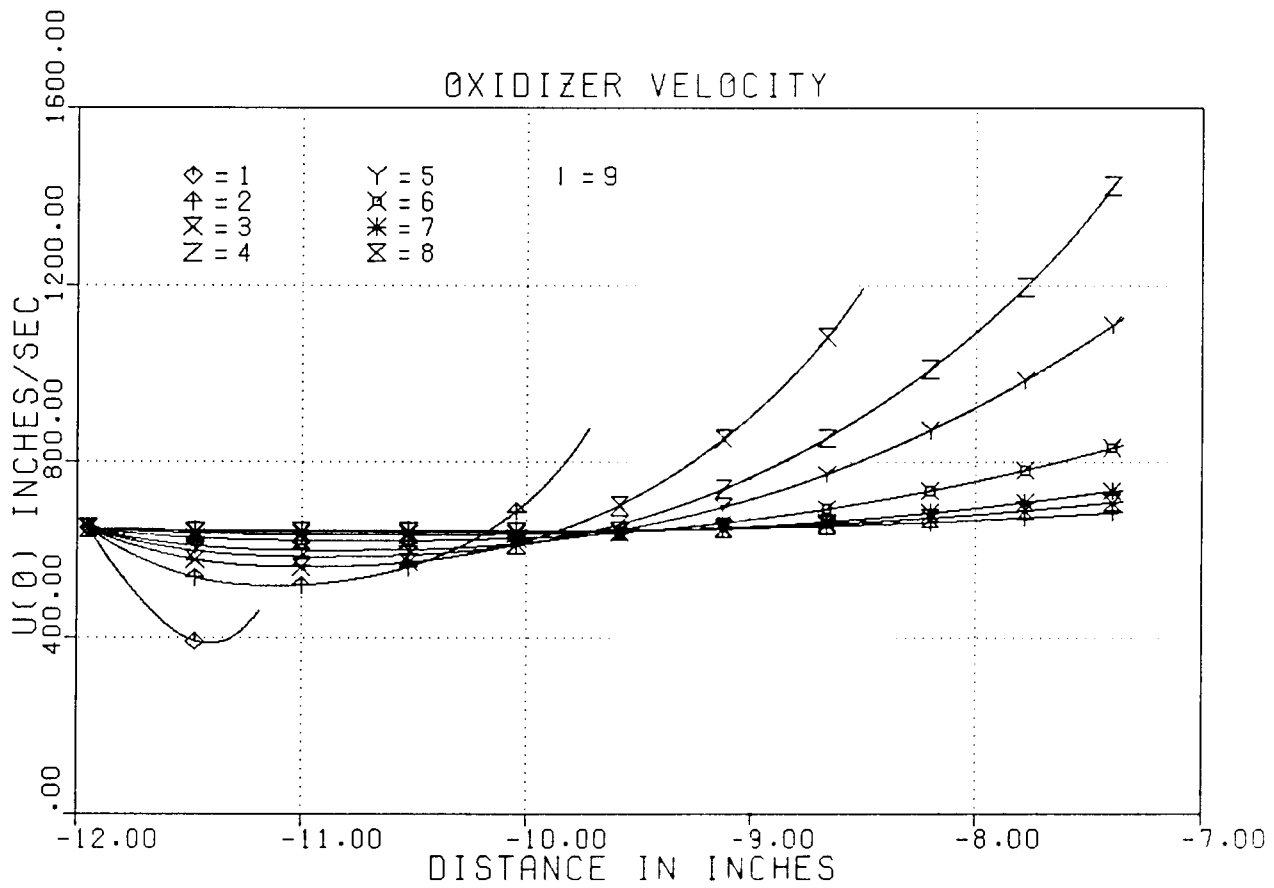
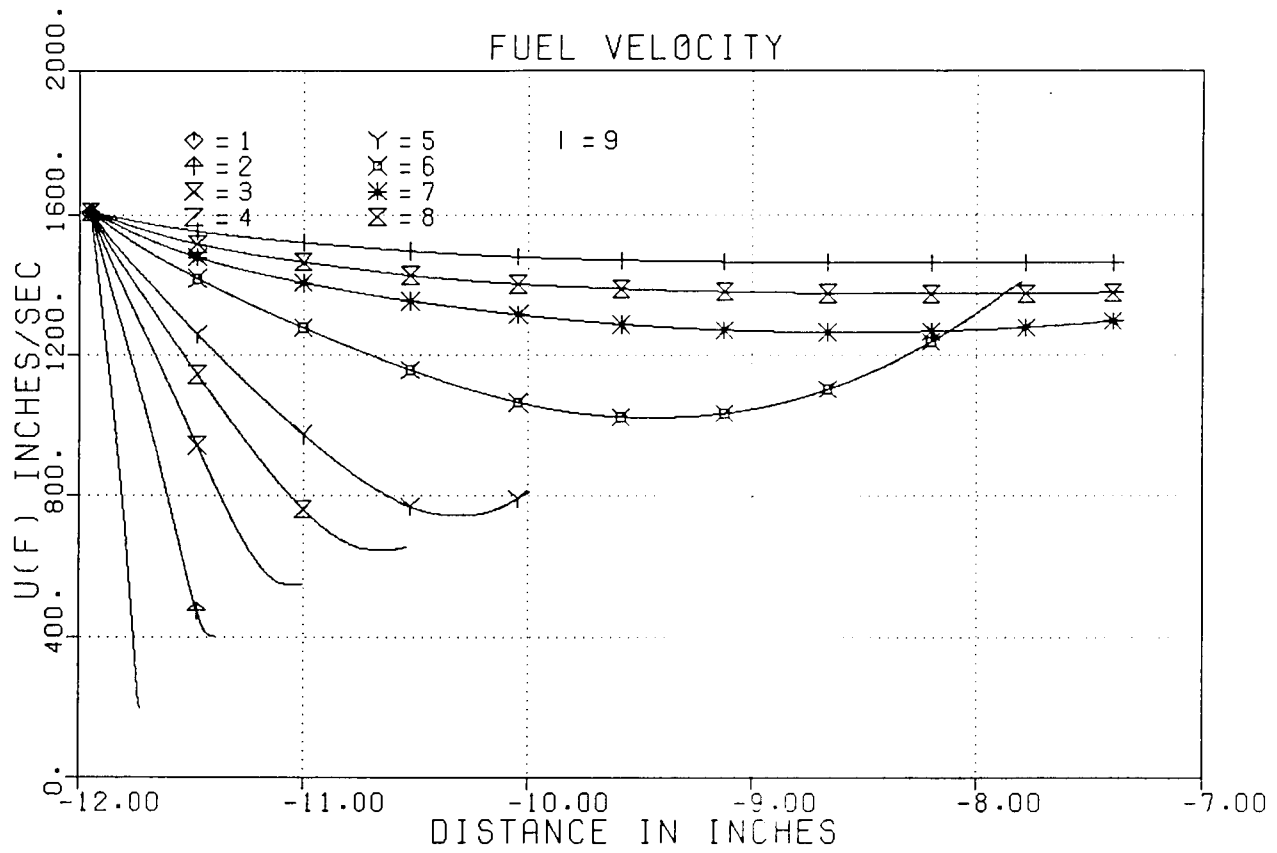
	OXIDIZER	FUEL	TOTAL	COMBUST.
BURNING RATE PARAMETER	.031455	.010960	.042415	.050051
DRAG PARAMETER	.58	1.07	1.65	

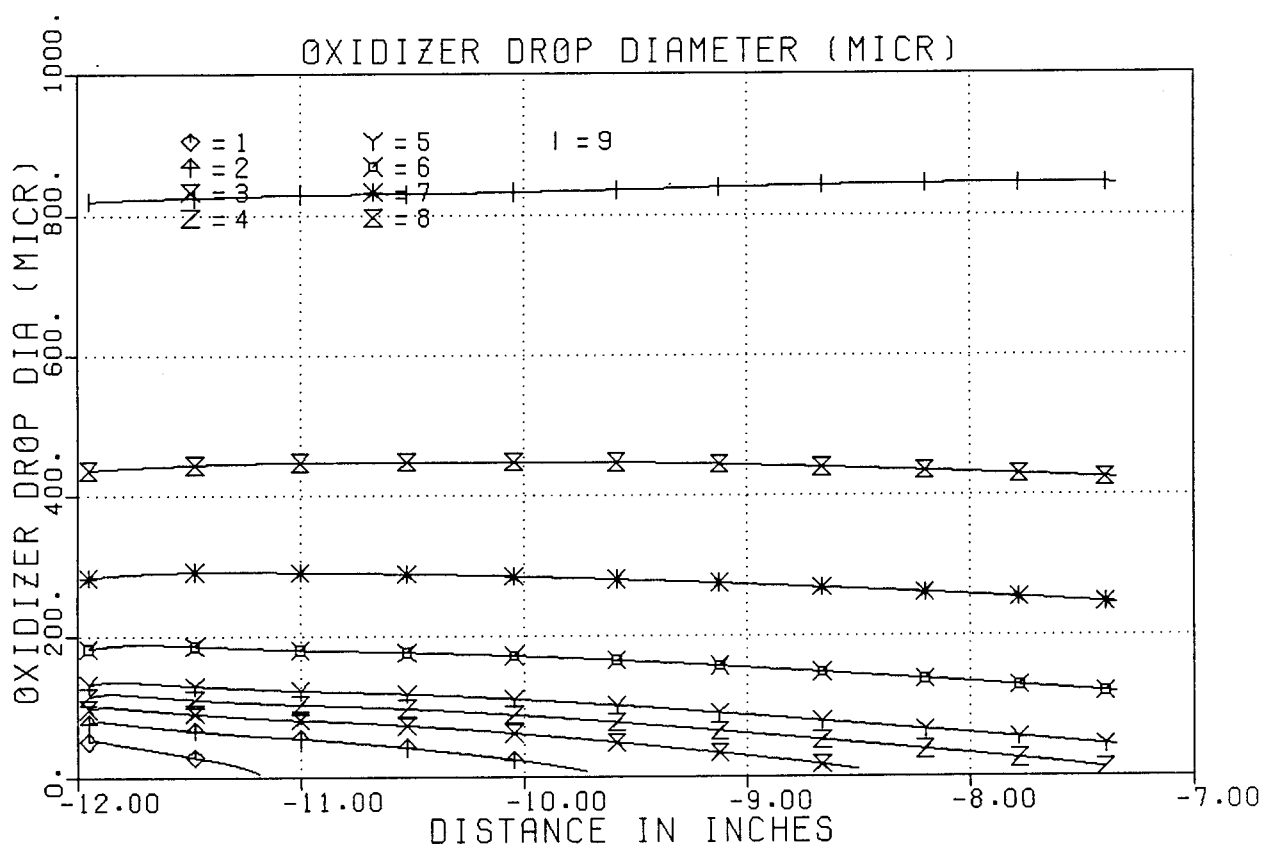
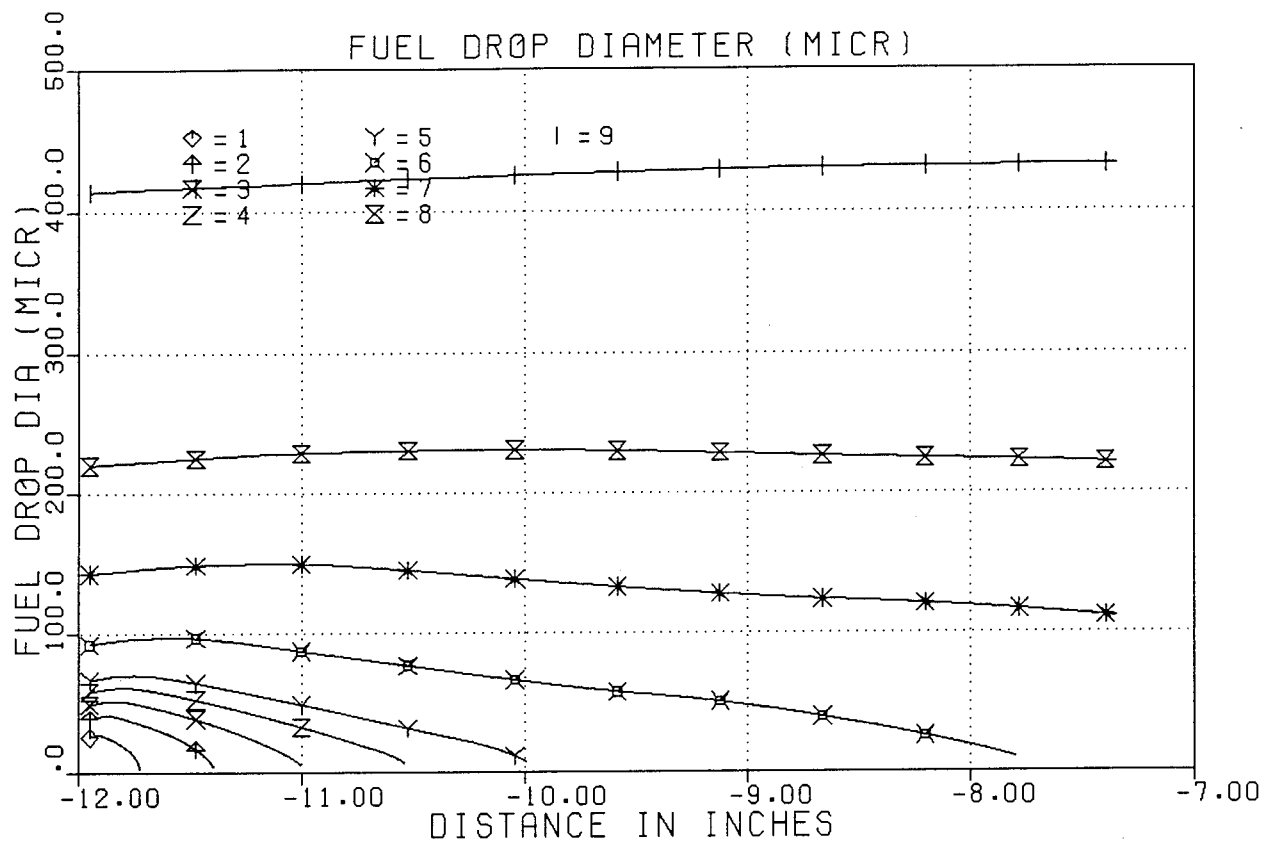
SCRIPT J .38205E-06

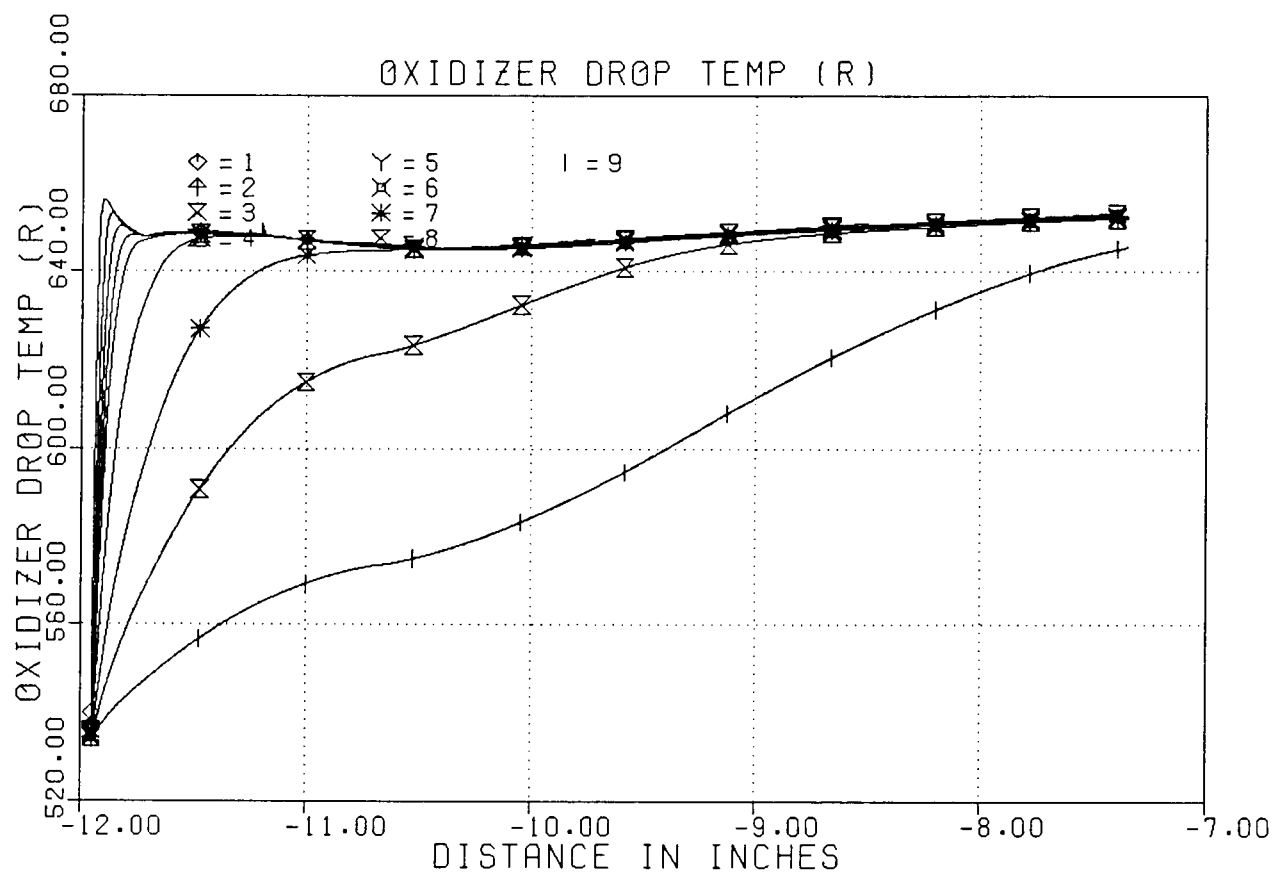
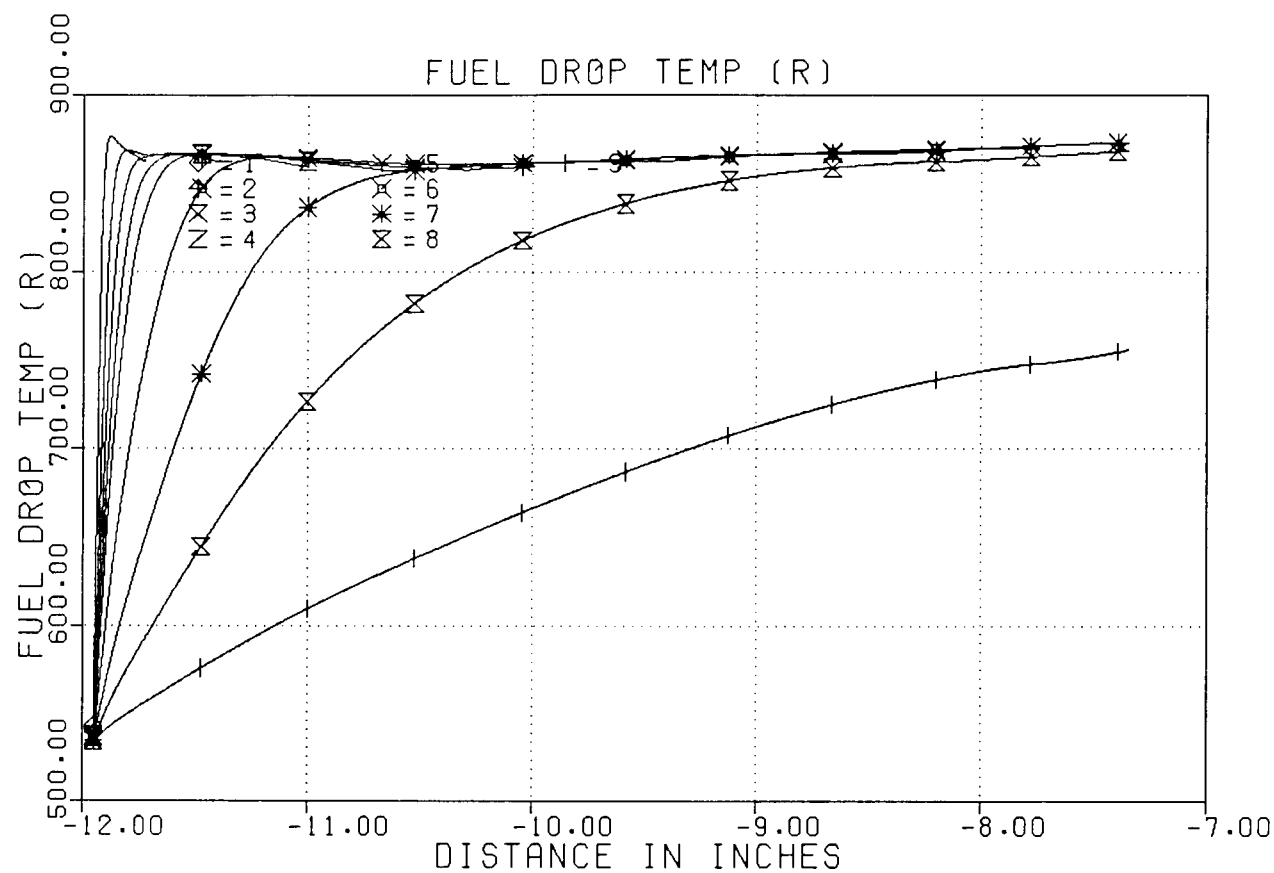
OINTEGRATION STEP= .0464

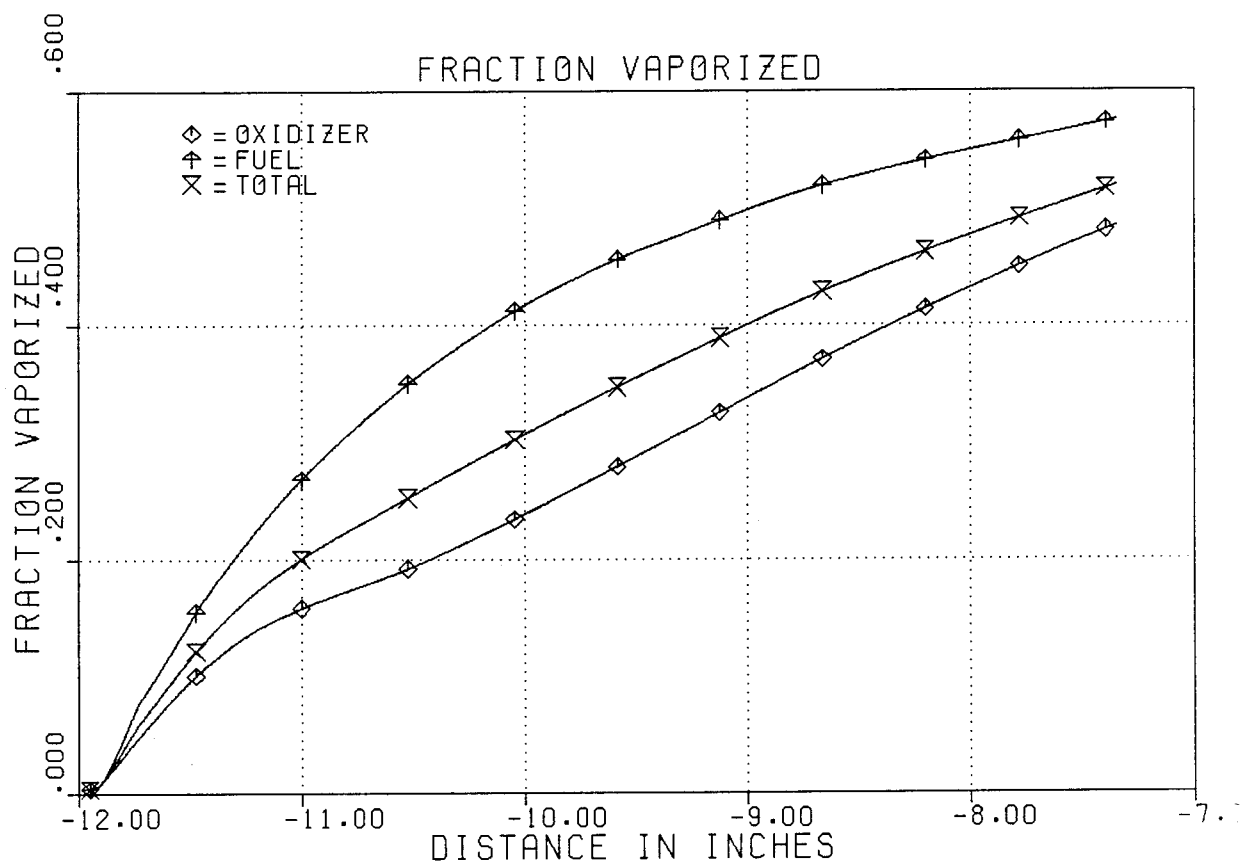
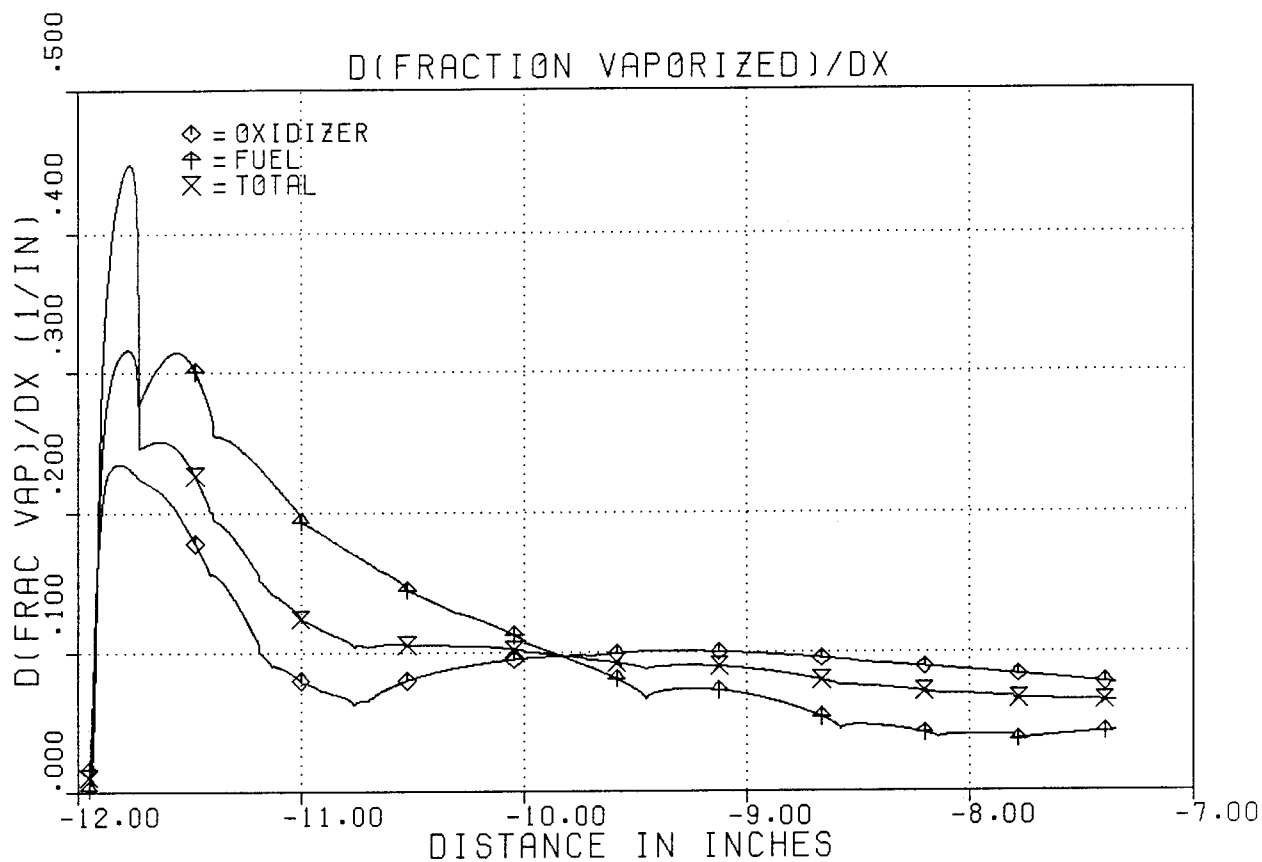
DATA FOR ODE/ODK SAVED ON UNIT 15

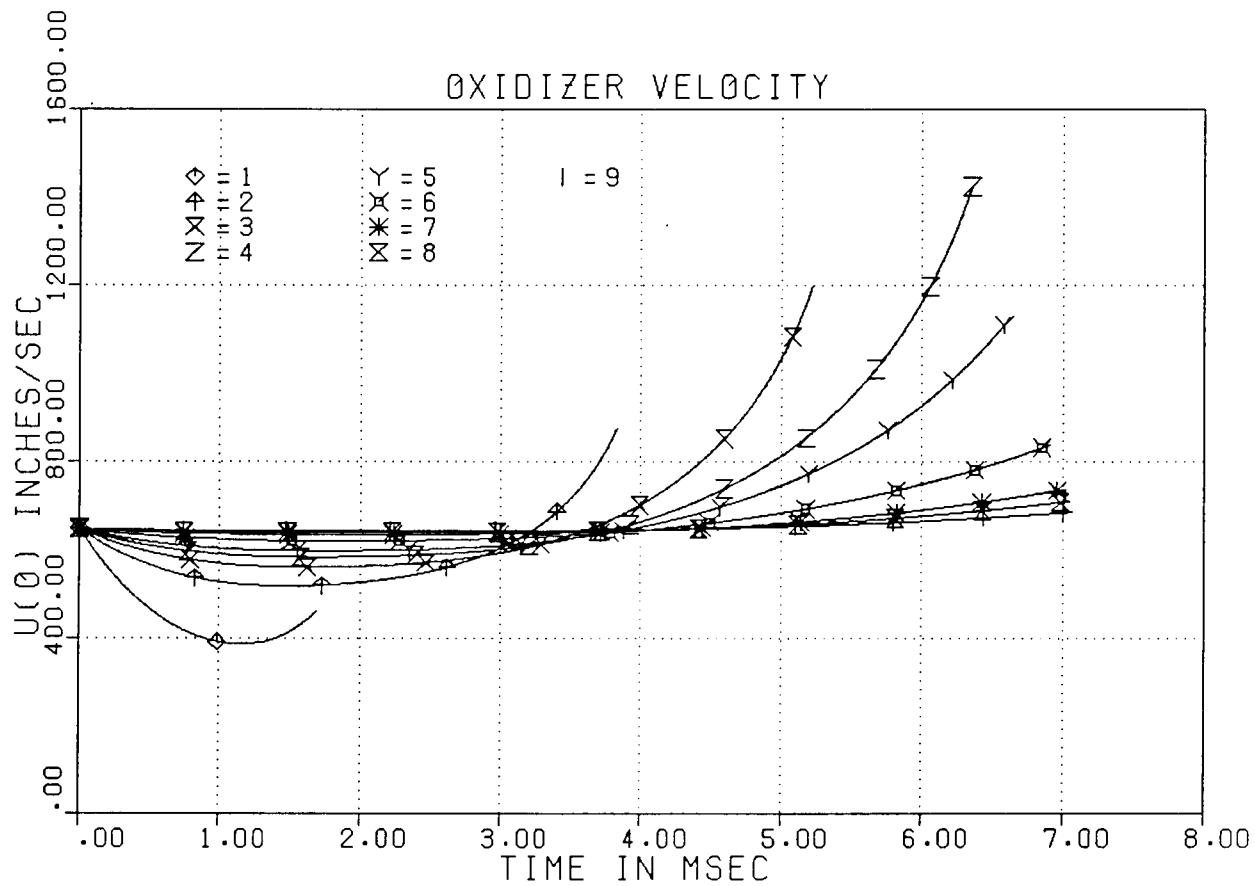
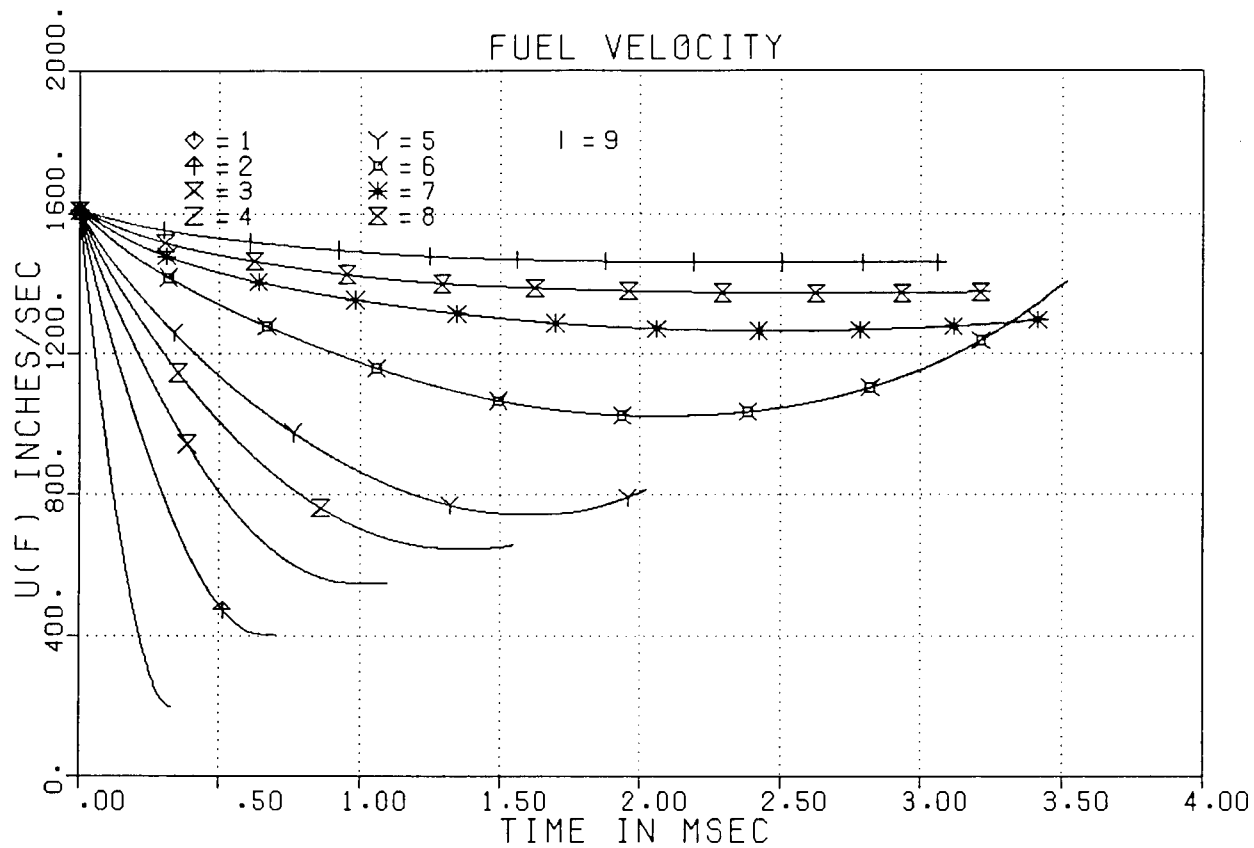


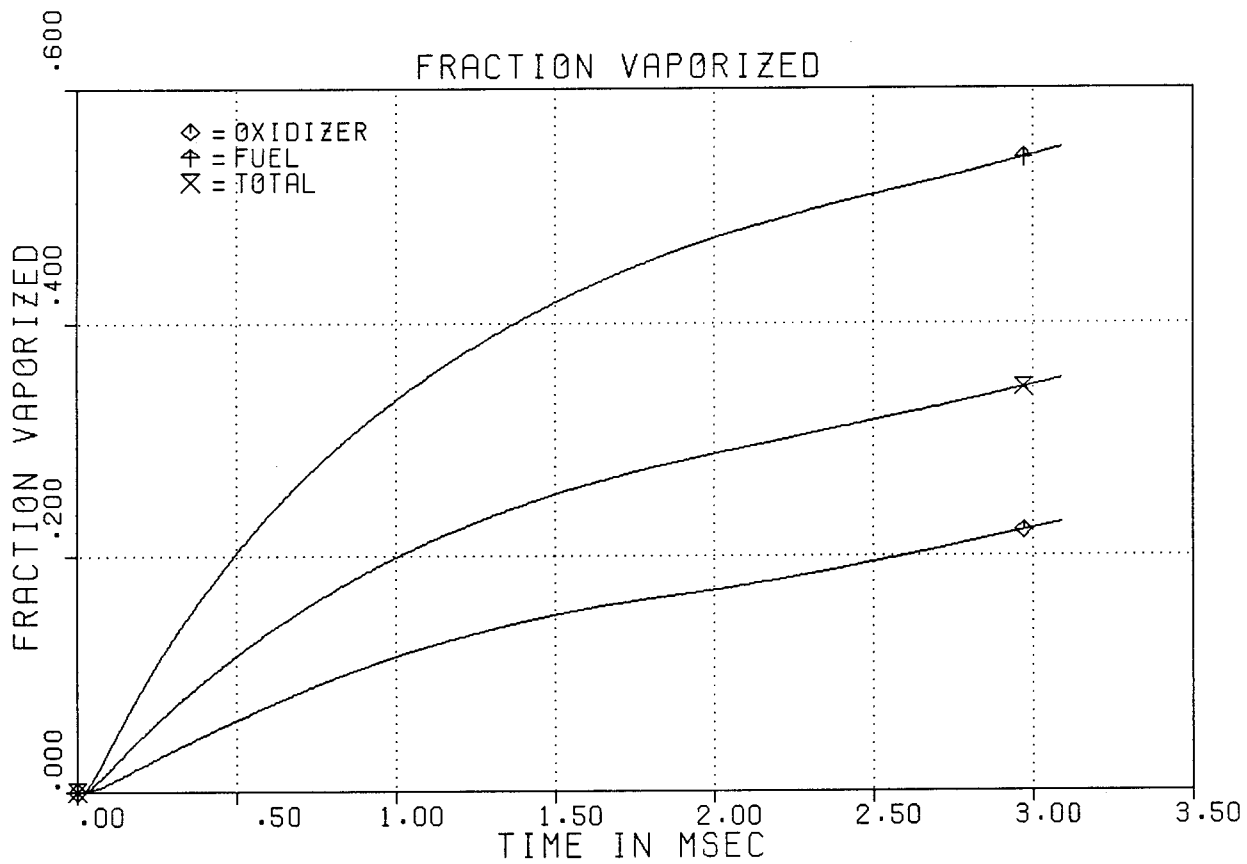
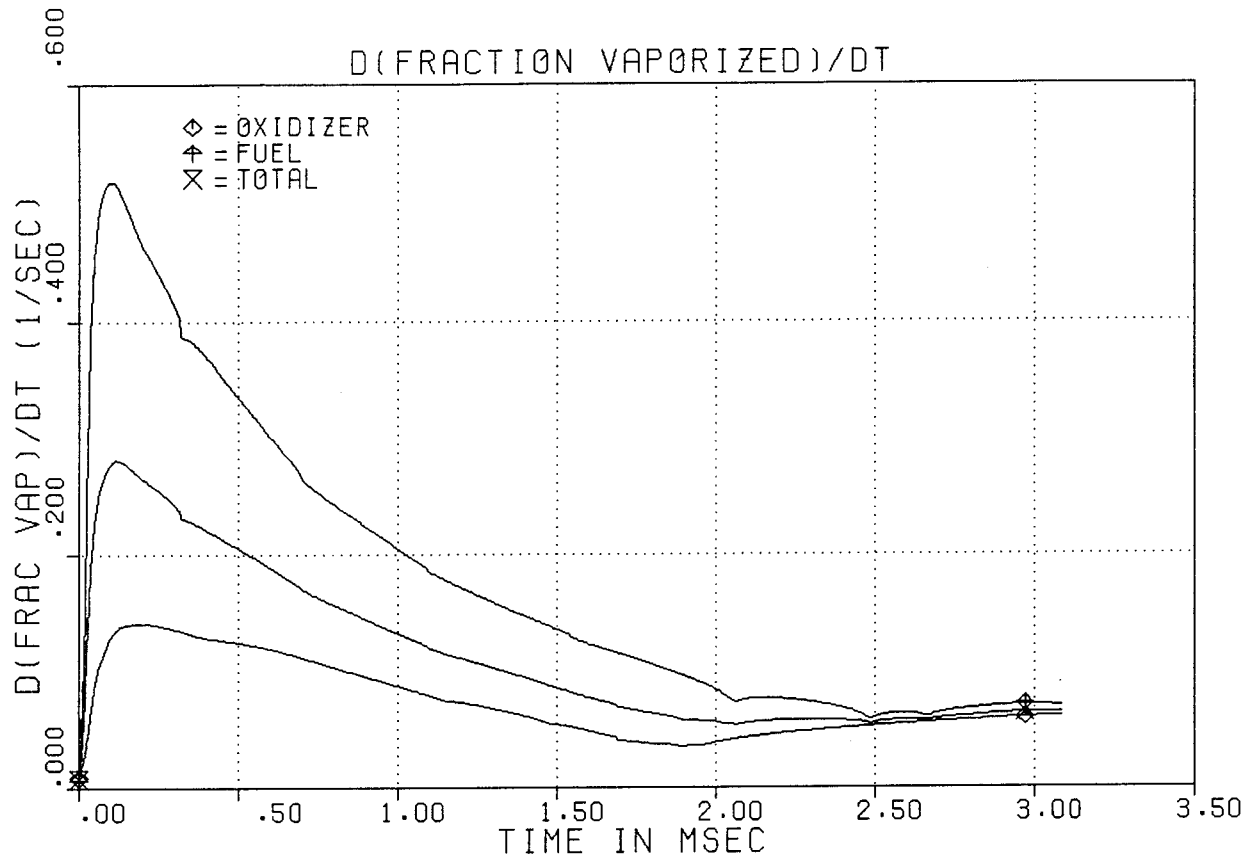












case3.dat

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TITLE CASE3 LOX/RP1 TRW 50K ENGINE
DATA
C LOX/RP-1    50K    PRIEM DROPSIZES          D30 LOX=BIMODAL DIST.
C PC = 235.0 MR=2.65 WT=169.0 TEST 650      D30 RP1=TRIMODAL DIST.
C CONSTANT AREA -- 2D DROP TRAJECTORY RUN
$DATA
  SCAP=1,
  RSI=6.125,
  ECRAT=3.8384,
  RI=.01
  THETAI=45.,
  RWTU=.5,
  ZT=3.76,
  NZONES=1,
$END
$SCAP
  FILENAME='RP1.DAT',
  XI(1)= 35.7,
  DXI(1)= 2.0,
  INDX=0,
  IPART=2,
  TWOD=1,
  NSET=10,10,
  DS(1,1)= 54., 96., 132., 174., 226., 300., 416., 714., 48., 148.,
  DS(1,2)= 170., 320., 494., 764.,1436., 146., 294., 498., 996., 214.,
  P= 235.0,
  U= 0,
  EMDOT(1)= 122.7, 46.3,
  DIY= 3.16,
  VIY(1,1)= 1065., 1065., 1065., 1065., 1065., 1065., 1065., 1065., 1042., 1042.,
  VIY(1,2)= 1065., 1065., 1065., 1065., 1065., 1042., 1042., 1042., 1042., 1072.,
  VIX(1,1)= 153.4, 153.4, 153.4, 153.4, 153.4, 153.4, 153.4, 153.4, 254.3, 254.3,
  VIX(1,2)= 153.4, 153.4, 153.4, 153.4, 153.4, 254.3, 254.3, 254.3, 254.3, 1072.,
  TLL(1)= 180., 530.,
  RATMN= .2,
  RATMX= 20.,
  BRNMAX = .499,
  OFSTOC= 3.4,
  PLTPROP=F,
  IFPLOT=10*1,5*0,1, FAC1=.9,
$END

```

case3.out

```

*****
TWO DIMENSIONAL KINETIC PROGRAM (TDF), LPP VERSION, MAY 1993

SOFTWARE AND ENGINEERING ASSOCIATES, INC.
1000 E WILLIAM STREET, SUITE 200, CARSON CITY NEVADA 89701
(702) 882 1966
EMAIL: UUNET:SEASERVISTU
*****

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```

1
TITLE CASE3 LOX/RP1 TRW 50K ENGINE
DATA
C LOX/RP-1 50K PRIEM DROPSIZES          D30 LOX=BIMODAL DIST.
C PC = 235.0 MR=2.65 WT=169.0 TEST 650  D30 RP1=TRIMODAL DIST.
C CONSTANT AREA -- 2D DROP TRAJECTORY RUN
$DATA
SCAP=1,
RSI=6.125,
ECRAT=3.8384,
RI=.01
THERAI=45.,
AWTU=.5,
ZT=3.76,
MZONES=1,
$END
$SCAP
FILENAME='RP1.DAT',
XI(1)= 35.7,
DXI(1)= 2.0,
INDX=0,
IPART=2,
TWOD=1,
NSET=10,10,
DS(1,1)= 54., 96., 132., 174., 226., 300., 416., 714., 48., 148.,
DS(1,2)= 170., 320., 494., 764.,1436., 146., 294., 498., 996., 214.,
P= 235.0,
U= 0,
ENDOT(1)= 122.7, 46.3,
DIY= 3.16,
VIY(1,1)= 1065., 1065., 1065., 1065., 1065., 1065., 1065., 1065., 1042., 1042.
VIY(1,2)= 1065., 1065., 1065., 1065., 1065., 1042., 1042., 1042., 1042., 1072.
VIX(1,1)= 153.4, 153.4, 153.4, 153.4, 153.4, 153.4, 153.4, 153.4, 254.3, 254.3
VIX(1,2)= 153.4, 153.4, 153.4, 153.4, 153.4, 254.3, 254.3, 254.3, 254.3, 1072.
TLL(1)= 180., 530.,
RATON= .2,
RATON= 20.,
BRNMAX = .499,
OFSTOC= 3.4,
PLTPROP=F,
IFPLOT=10*1,5*0,1, FAC1=.9,

```

case3.out

```

$END
01TITLE CASE3 LOX/RF1 TRW 50K ENGINE
0DATA
C LOX/RF-1 50K PRIEM DROPSIZES D30 LOX=BIMODAL DIST.
C PC = 235.0 MR=2.65 WT=169.0 TEST 650 D30 RF1=TRIMODAL DIST.
C CONSTANT AREA -- 2D DROP TRAJECTORY RUN
$DATA
SCAP=1,
RSI=6.125,
ECRAT=3.8384,
RI=.01,
THETA=45.,
RWTU=.5,
ZT=3.76,
NZONES=1,
$END
$SCAP
FILENAME='RP1.DAT',
XI(1)= 35.7,
DXI(1)= 2.0,
INDX=0,
IPART=2,
TWOD=1,
NSET=10,10,
DB(1,1)= 54., 96., 132., 174., 226., 300., 416., 714., 48., 148.,
DB(1,2)= 170., 320., 494., 764., 1436., 146., 294., 498., 996., 214.,
P= 235.0,
U= 0,
ENDOT(1)= 122.7, 46.3,
DIY= 3.16,
VIY(1,1)= 1065., 1065., 1065., 1065., 1065., 1065., 1065., 1065., 1042., 1042.
VIY(1,2)= 1065., 1065., 1065., 1065., 1065., 1042., 1042., 1042., 1042., 1072.
VIX(1,1)= 153.4, 153.4, 153.4, 153.4, 153.4, 153.4, 153.4, 153.4, 254.3, 254.3
VIX(1,2)= 153.4, 153.4, 153.4, 153.4, 153.4, 254.3, 254.3, 254.3, 254.3, 1072.
TLL(1)= 180., 530.,
RATMN= .2,
RATMX= 20.,
BRNMAX = .499,
OFFSTOC= 3.4,
PLTPROP=F,
IFPLOT=10*1,5*0,1, FAC1=.9,
$END
$INPUT
PCRT=731, 315,
FLAMEF= 2, TFLAME=6458.,
NAMES='LOX', 'RF-1',
NPRES= 3,
NSP= 9,
SPNAME= ' CH4', ' CO', ' CO2', ' H', ' H2', ' H2O',
' O', ' O2', ' OH',
WM(1)= 16.04, 28.01, 44.01, 1.01, 2.02, 18.02, 16.00, 32.00, 17.01,
EPSI(1,1)= 148.600, 91.700, 195.200, 37.000, 59.700, 809.100, 106.700, 106.700, 79.800,
SIGMA(1,1)= 3.7580, 3.6900, 3.9410, 2.7080, 2.8270, 2.6410, 3.0500, 3.4670, 3.1470,
SIGOF= 3.4670, 7.5620, WTMOL= 32.0000, 172.000, FLAME2= F,
PRSS= 200.000, 250.000, 350.000, EPSOF= 106.700, 521.000,
NR= 6,
R(1)= 20.000, 10.000, 5.000, 2.400, 1.000, 0.100,
YSP(1,1,1)= 0.0, 0.0, 0.0, 0.0, 0.0099, 0.5470,
YSP(1,2,1)= 0.0000, 0.0086, 0.1087, 0.3465, 0.4679, 0.0080,
YSP(1,3,1)= 0.1082, 0.1935, 0.2220, 0.1202, 0.0024, 0.0070,
YSP(1,4,1)= 0.0000, 0.0007, 0.0130, 0.0433, 0.0000,
YSP(1,5,1)= 0.0000, 0.0012, 0.0165, 0.1102, 0.5132, 0.3239,
YSP(1,6,1)= 0.1064, 0.1841, 0.2602, 0.3017, 0.0066, 0.1139,
YSP(1,7,1)= 0.0000, 0.0093, 0.0403, 0.0123,
YSP(1,8,1)= 0.7850, 0.5759, 0.2540, 0.0133,
YSP(1,9,1)= 0.0003, 0.0267, 0.0851, 0.0524,
YSP(1,1,2)= 0.0, 0.0, 0.0, 0.0, 0.0117, 0.5586,
YSP(1,2,2)= 0.0000, 0.0080, 0.1070, 0.3468, 0.4676, 0.0081,
YSP(1,3,2)= 0.1082, 0.1942, 0.2247, 0.1212, 0.0028, 0.0071,
YSP(1,4,2)= 0.0000, 0.0006, 0.0123, 0.0415, 0.0000,
YSP(1,5,2)= 0.0000, 0.0011, 0.0160, 0.1099, 0.5103, 0.3114,
YSP(1,6,2)= 0.1064, 0.1847, 0.2620, 0.3045, 0.0076, 0.1147,
YSP(1,7,2)= 0.0000, 0.0087, 0.0390, 0.0116,
YSP(1,8,2)= 0.7850, 0.5766, 0.2540, 0.0127,
YSP(1,9,2)= 0.0003, 0.0260, 0.0848, 0.0517,
YSP(1,1,3)= 0.0, 0.0, 0.0, 0.0, 0.0148, 0.5763,
YSP(1,2,3)= 0.0000, 0.0073, 0.1042, 0.3471, 0.4673, 0.0082,
YSP(1,3,3)= 0.1082, 0.1952, 0.0229, 0.1228, 0.0033, 0.0072,
YSP(1,4,3)= 0.0, 0.0005, 0.0113, 0.0388, 0.0000,
YSP(1,5,3)= 0.0000, 0.0010, 0.0154, 0.1093, 0.5052, 0.2923,
YSP(1,6,3)= 0.1064, 0.1857, 0.2646, 0.0309, 0.0094, 0.1160,
YSP(1,7,3)= 0.0000, 0.0078, 0.0371, 0.0106,
YSP(1,8,3)= 0.7851, 0.5775, 0.2540, 0.0119,
YSP(1,9,3)= 0.0003, 0.0249, 0.0844, 0.0506,
WMTAB(1,1)= 31.8060, 31.1100, 27.7770, 22.2140, 14.3660, 12.0140,
WMTAB(1,2)= 31.8060, 31.1370, 27.8500, 22.2730, 14.4120, 12.1050,
WMTAB(1,3)= 31.8070, 31.1750, 27.9610, 22.3630, 14.4950, 12.2420,
TC1(1,1)= 3133.50, 4960.10, 5958.60, 6144.90, 2662.30, 1596.00,
TC1(1,2)= 3133.70, 4978.50, 6009.60, 6198.40, 2679.90, 1612.40,
TC1(1,3)= 3133.90, 5005.20, 6086.90, 6278.90, 2709.80, 1636.90,
PGANT(1)= 1.255, 1.218, 1.209, 1.223, 1.262, 1.296,
MT= 6,
TTAB(1)= 540.00, 1080.00, 1980.00, 3060.00, 4860.00, 7020.00,
VSP(1,1)= 0.6277, 1.0780, 1.6370, 2.1770, 2.9420, 3.7350,
VSP(1,2)= 0.9939, 1.6230, 2.4160, 3.2090, 4.3320, 5.4930,
VSP(1,3)= 0.8512, 1.5200, 2.3500, 3.1490, 4.2450, 5.4020,
VSP(1,4)= 0.4194, 0.6580, 0.9755, 1.2918, 1.7409, 2.2070,
VSP(1,5)= 0.4995, 0.7952, 1.1790, 1.5634, 2.1077, 2.6716,
VSP(1,6)= 0.6137, 1.2033, 2.2018, 3.2518, 4.6926, 6.1211,
VSP(1,7)= 1.0561, 1.7466, 2.6156, 3.4679, 4.6870, 5.9441,
VSP(1,8)= 1.1558, 1.9118, 2.8626, 3.7955, 5.1299, 6.5058,

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case3.out

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VSP(1,9)= 1.1065, 1.7807, 2.6403, 3.5110, 4.7368, 6.0046,
CPTAB(1,1)= 8.535, 12.484, 18.052, 21.580, 23.895, 24.855,
CPTAB(1,2)= 6.965, 7.275, 8.056, 8.533, 8.837, 8.986,
CPTAB(1,3)= 8.863, 11.266, 13.201, 14.145, 14.732, 15.022,
CPTAB(1,4)= 4.968, 4.968, 4.968, 4.968, 4.968, 4.968,
CPTAB(1,5)= 6.995, 7.009, 7.307, 7.907, 8.637, 9.125,
CPTAB(1,6)= 8.028, 8.680, 10.163, 11.699, 13.122, 13.933,
CPTAB(1,7)= 5.234, 5.050, 4.994, 4.980, 4.990, 5.081,
CPTAB(1,8)= 7.023, 7.671, 8.438, 8.853, 9.388, 9.859,
CPTAB(1,9)= 6.965, 7.003, 7.422, 8.046, 8.666, 9.038,
NTL= 1, 10,
TLI(1,2)= 460.00, 530.00, 560.00, 660.00, 760.00, 860.00,
          960.00, 1060.00, 1160.00, 1218.00,
FV(1,2)= 0.002, 0.003, 0.010, 0.210, 2.100, 11.000,
          36.000, 100.000, 220.000, 315.000,
RHOL(1,2)= .029740, .028870, .028410, .027200, .025640, .023900,
            .022000, .019560, .015740, .009840,
CP(1,2)= 0.43500, 0.47000, 0.48500, 0.54000, 0.59000, 0.64700,
          0.70000, 0.77500, 0.86000, 0.90100,
LAM(1,2)= 144.300, 139.200, 137.000, 128.900, 120.000, 109.800,
          97.770, 82.660, 60.740,
NTFLM= 7, 6,
TFILM(1,1)= 180.00, 540.00, 1080.00, 1800.00, 2700.00, 3600.00, 5400.00,
TFILM(1,2)= 360.00, 540.00, 720.00, 900.00, 1080.00, 1260.00,
VVIS(1,1)= 0.45940, 1.23790, 2.04750, 2.88240, 3.74240, 4.52090, 5.88170,
VVIS(1,2)= 0.15700, 0.24600, 0.33600, 0.42000, 0.48200, 0.53800,
KVAP(1,1)= 0.145, 0.393, 0.705, 1.125, 1.453, 1.809, 2.476,
KVAP(1,2)= 0.126, 0.174, 0.278, 0.394, 0.498, 0.607,
CPVAP(1,1)= 0.217, 0.220, 0.240, 0.261, 0.273, 0.282, 0.298,
CPVAP(1,2)= 0.275, 0.380, 0.470, 0.562, 0.650, 0.725,
$END

```

STEADY-STATE SPRAY COMBUSTION MODEL

```

0      MASS FLOW  RM      SIG  MOLE WT
O      122.70    .000E+00  .00  32.00
F      46.30     .000E+00  .00  172.00
1      CASE3 LOX/RP1 TRW 50K ENGINE

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OX=-23.030 U= .0 T=3134. TO=3134. P= 235.00 PO= 235.00 O/F= .2000E+02 MACH=.000 AREA= 452.39 DADK=.000E+00
OVAPORIZED FRACTION O .000019 F .000000 BOTH .000014 COMB .000000 SOUND SPEED=.298E+05
VAPORIZATION RATE/IN O .185703 F .000007 BOTH .134829 COMB .000008

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	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
OXIDIZER DROPS									
1	54.0306	.20173E-09	153.	-.0052	180.83	.608E+11	.659E-04	-.639E+00	3.16
2	96.0203	.11335E-08	153.	-.0052	180.31	.108E+11	.245E-04	-.237E+00	3.16
3	132.0163	.29467E-08	153.	-.0052	180.18	.416E+10	.143E-04	-.139E+00	3.16
4	174.0135	.67495E-08	153.	-.0052	180.12	.182E+10	.901E-05	-.879E-01	3.16
5	226.0114	.14789E-07	153.	-.0052	180.07	.830E+09	.589E-05	-.573E-01	3.16
6	300.0095	.34593E-07	153.	-.0052	180.05	.355E+09	.370E-05	-.363E-01	3.16
7	416.0078	.92237E-07	153.	-.0052	180.03	.133E+09	.216E-05	-.215E-01	3.16
8	714.0056	.46636E-06	153.	-.0052	180.01	.263E+08	.914E-06	-.911E-02	3.16
9	48.0232	.14169E-09	254.	-.0085	180.71	.866E+11	.563E-04	-.548E+00	3.16
10	148.0108	.41534E-08	254.	-.0085	180.11	.295E+10	.855E-05	-.834E-01	3.16
OFUEL DROPS									
1	170.0092	.45320E-08	153.	-.0052	530.31	.102E+10	.000E+00	-.204E-04	3.16
2	320.0060	.30227E-07	153.	-.0052	530.11	.153E+09	.000E+00	-.711E-05	3.16
3	494.0045	.11121E-06	153.	-.0052	530.05	.416E+08	.000E+00	-.353E-05	3.16
4	764.0034	.41136E-06	153.	-.0052	530.03	.113E+08	.000E+00	-.175E-05	3.16
5	1436.0022	.27315E-05	153.	-.0052	530.01	.170E+07	.000E+00	-.646E-06	3.16
6	146.0072	.28708E-08	254.	-.0085	530.28	.161E+10	.000E+00	-.187E-04	3.16
7	294.0045	.23442E-07	254.	-.0085	530.09	.198E+09	.000E+00	-.598E-05	3.16
8	498.0032	.11393E-06	254.	-.0085	530.04	.406E+08	.000E+00	-.256E-05	3.16
9	996.0020	.91443E-06	254.	-.0085	530.01	.508E+07	.000E+00	-.861E-06	3.16
10	214.0022	.30404E-08	1072.	-.0360	530.06	.512E+09	.000E+00	-.428E-05	3.16

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          OXIDIZER      FUEL      TOTAL      COMBUST.
BURNING RATE PARAMETER .268341 .000004 .268344 .000025
DRAG PARAMETER         156.06    11.35    167.41

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SCRIPT J .13774E-06
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0 INTEGRATION STEP= .0001
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OX. DROP GROUP 1 IS BOILING
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OX. DROP GROUP 2 IS BOILING
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OX. DROP GROUP 3 IS BOILING
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OX. DROP GROUP 10 IS BOILING
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1 CASE3 LOX/RP1 TRW 50K ENGINE
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OX=-21.030 U= 3821.2 T=5540. TO=5545. P= 232.69 PO= 233.95 O/F= .7191E+01 MACH=.094 AREA= 452.39 DADK=.000E+00
OVAPORIZED FRACTION O .820222 F .302293 BOTH .678328 COMB .364397 SOUND SPEED=.406E+05
VAPORIZATION RATE/IN O .056504 F .099246 BOTH .068214 COMB .119635

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	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
OXIDIZER DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	46.1797	.10567E-09	2043.	.0438	228.93	.182E+10	.984E+00	-.520E-01	4.88
5	124.3229	.20618E-08	1627.	.0541	228.95	.830E+09	.861E+00	-.130E+00	5.39
6	219.2935	.11315E-07	1444.	.0586	228.95	.355E+09	.673E+00	-.147E+00	5.95
7	357.7855	.49140E-07	1284.	.0626	228.95	.133E+09	.467E+00	-.129E+00	6.59
8	697.2107	.36362E-06	1076.	.0677	228.96	.263E+08	.220E+00	-.840E-01	7.56
9	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
10	23.0835	.13197E-10	2594.	.0303	228.95	.295E+10	.997E+00	-.230E-01	4.68
OFUEL DROPS									
1	56.6776	.10417E-09	2263.	.0384	1103.29	.102E+10	.977E+00	-.712E-01	4.49
2	319.8350	.18813E-07	1601.	.0548	1100.93	.153E+09	.378E+00	-.207E+00	5.60
3	547.2622	.10417E-06	1363.	.0606	1046.47	.416E+08	.633E-01	-.697E-01	6.41
4	819.0189	.40953E-06	1166.	.0655	890.03	.113E+08	.446E-02	-.623E-02	7.18
5	1478.1162	.27312E-05	946.	.0709	706.89	.170E+07	.123E-03	-.159E-03	8.19
6	32.1328	.19018E-10	2718.	.0272	1102.41	.161E+10	.993E+00	-.364E-01	4.38

case3.out

7	296.6941	.15037E-07	1626.	.0541	1100.34	.198E+09	.359E+00	-.232E+00	5.36
8	549.7826	.11036E-06	1343.	.0611	1009.80	.406E+08	.313E-01	-.469E-01	6.07
9	1036.8435	.91106E-06	1066.	.0679	763.42	.508E+07	.405E-03	-.541E-03	6.87
10	229.4679	.70805E-08	1773.	.0505	1091.94	.512E+09	.217E+00	-.323E+00	4.42

	OXIDIZER	FUEL	TOTAL	COMBUST.
BURNING RATE PARAMETER	.115685	.076673	.192359	.374015
DRAG PARAMETER	.79	1.24	2.03	

SCRIPT J .27114E-06
 OINTEGRATION STEP= .0003
 OX. DROP GROUP 4 IS BOILING
 OX. DROP GROUP 5 IS BOILING
 1 CASE3 LOX/RP1 TRW 50K ENGINE

OX=-19.030 U= 4837.0 T=5930. TO=5937. P= 231.77 PO= 233.56 O/F= .5263E+01 MACH= .113 AREA= 452.39 DADX= .000E+00
 OVAPORIZED FRACTION O .884558 F .445440 BOTH .764255 COMB .536953 SOUND SPEED= .428E+05
 VAPORIZATION RATE/IN O .019673 F .053743 BOTH .029007 COMB .064784

	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
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OXIDIZER DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	53.1641	.16125E-09	2941.	.0443	228.92	.830E+09	.989E+00	-.213E-01	5.73
6	165.0225	.48228E-08	2424.	.0563	228.91	.355E+09	.861E+00	-.599E-01	6.43
7	311.0908	.32308E-07	2148.	.0628	228.92	.133E+09	.650E+00	-.664E-01	7.22
8	657.4283	.30492E-06	1811.	.0706	228.92	.263E+08	.346E+00	-.491E-01	8.50
9	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
10	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00

OFUEL DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	260.5099	.10098E-07	2621.	.0517	1104.09	.153E+09	.666E+00	-.100E+00	5.98
3	528.5990	.86417E-07	2271.	.0599	1092.68	.416E+08	.223E+00	-.800E-01	6.99
4	841.4923	.40087E-06	1963.	.0671	998.73	.113E+08	.255E-01	-.158E-01	7.98
5	1500.6726	.27299E-05	1606.	.0754	780.62	.170E+07	.585E-03	-.373E-03	9.35
6	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
7	236.1736	.75245E-08	2664.	.0507	1104.07	.198E+09	.679E+00	-.109E+00	5.79
8	544.2641	.96006E-07	2242.	.0606	1084.17	.406E+08	.157E+00	-.727E-01	6.73
9	1061.8212	.90866E-06	1793.	.0711	867.64	.508E+07	.303E-02	-.198E-02	7.89
10	168.0326	.27110E-08	2819.	.0471	1103.89	.512E+09	.700E+00	-.157E+00	4.93

	OXIDIZER	FUEL	TOTAL	COMBUST.
BURNING RATE PARAMETER	.042822	.044141	.086964	.202535
DRAG PARAMETER	.28	.57	.85	

SCRIPT J .29701E-06
 OINTEGRATION STEP= .0037
 OX. DROP GROUP 6 IS BOILING
 1 CASE3 LOX/RP1 TRW 50K ENGINE

OX=-17.030 U= 5419.1 T=6013. TO=6023. P= 231.29 PO= 233.41 O/F= .4554E+01 MACH= .123 AREA= 452.39 DADX= .000E+00
 OVAPORIZED FRACTION O .913217 F .531372 BOTH .808605 COMB .640539 SOUND SPEED= .441E+05
 VAPORIZATION RATE/IN O .010929 F .034153 BOTH .017292 COMB .041149

	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
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OXIDIZER DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
6	120.3978	.18726E-08	3141.	.0517	228.94	.355E+09	.946E+00	-.299E-01	6.74
7	275.4839	.22447E-07	2763.	.0602	228.82	.133E+09	.757E+00	-.434E-01	7.65
8	628.0588	.26598E-06	2340.	.0699	228.83	.263E+08	.430E+00	-.361E-01	9.11
9	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
10	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00

OFUEL DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	212.3009	.54698E-08	3322.	.0476	1103.71	.153E+09	.819E+00	-.581E-01	6.24
3	496.1511	.70294E-07	2896.	.0572	1100.51	.416E+08	.368E+00	-.652E-01	7.37
4	846.3882	.38501E-06	2533.	.0655	1047.18	.113E+08	.641E-01	-.218E-01	8.51
5	1517.5970	.27271E-05	2089.	.0755	830.17	.170E+07	.164E-02	-.648E-03	10.12
6	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
7	186.3472	.36998E-08	3379.	.0463	1103.61	.198E+09	.842E+00	-.600E-01	6.07
8	517.0341	.80022E-07	2866.	.0579	1097.70	.406E+08	.298E+00	-.658E-01	7.17
9	1078.9305	.90312E-06	2320.	.0703	933.46	.508E+07	.912E-02	-.391E-02	8.57
10	111.5304	.79393E-09	3586.	.0416	1103.18	.512E+09	.912E+00	-.661E-01	5.26

	OXIDIZER	FUEL	TOTAL	COMBUST.
BURNING RATE PARAMETER	.024491	.028879	.053370	.128707
DRAG PARAMETER	.16	.36	.52	

SCRIPT J .30597E-06
 OINTEGRATION STEP= .0159
 1 CASE3 LOX/RP1 TRW 50K ENGINE

OX=-15.030 U= 5798.1 T=6037. TO=6048. P= 230.98 PO= 233.33 O/F= .4205E+01 MACH= .129 AREA= 452.39 DADX= .000E+00
 OVAPORIZED FRACTION O .930941 F .586653 BOTH .836618 COMB .747177 SOUND SPEED= .448E+05
 VAPORIZATION RATE/IN O .007134 F .022203 BOTH .011263 COMB .024745

	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
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OXIDIZER DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
6	76.4277	.47957E-09	3777.	.0451	228.73	.355E+09	.986E+00	-.121E-01	6.97
7	244.6581	.15730E-07	3256.	.0567	228.75	.133E+09	.829E+00	-.305E-01	7.98

case3.out

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8 603.4929 .23607E-06 2764. .0677 228.76 .263E+08 .494E+00 -.287E-01 9.60
9 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
10 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
OFUEL DROPS
1 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
2 168.4841 .27377E-08 3879. .0428 1103.06 .153E+09 .909E+00 -.343E-01 6.44
3 464.2437 .57343E-07 3383. .0539 1102.49 .416E+08 .484E+00 -.518E-01 7.67
4 843.2521 .36563E-06 2984. .0628 1072.46 .113E+08 .111E+00 -.257E-01 8.92
5 1531.3533 .27230E-05 2480. .0740 868.87 .170E+07 .312E-02 -.901E-03 10.72
6 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
7 140.3067 .15816E-08 3953. .0412 1102.91 .198E+09 .933E+00 -.326E-01 6.28
8 487.0387 .66366E-07 3352. .0546 1101.40 .406E+08 .417E+00 -.542E-01 7.51
9 1091.9760 .89441E-06 2744. .0681 980.57 .508E+07 .187E-01 -.613E-02 9.09
10 54.4188 .92479E-10 4503. .0289 1101.89 .512E+09 .990E+00 -.163E-01 5.49

OXIDIZER FUEL TOTAL COMBUST.
BURNING RATE PARAMETER .016260 .019095 .035354 .083675
DRAG PARAMETER .11 .26 .37

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SCRIPT J .31028E-06
OINTEGRATION STEP= .0007
1 CASE3 LOX/RP1 TRW 50K ENGINE

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OX=-13.030 U= 6045.9 T=6050. TO=6062. P= 230.76 PO= 233.27 O/F= .4006E+01 MACH= .134 AREA= 452.39 DADX= .000E+00
OVAPORIZED FRACTION O .942762 F .623741 BOTH .855362 COMB .751884 SOUND SPEED= .453E+05
VAPORIZATION RATE/IN O .004601 F .015729 BOTH .007650 COMB .018961
0 D(MICR) MASS(LB) V(IN/SEC) U-V/A TEMP NUMBER (MI-M)/MI (DM/DX)/MI RAD POSIT.
OXIDIZER DROPS
1 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
2 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
3 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
4 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
5 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
6 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
7 216.6047 .10918E-07 3660. .0527 228.70 .133E+09 .882E+00 -.222E-01 8.25
8 581.9456 .21173E-06 3111. .0648 228.71 .263E+08 .546E+00 -.238E-01 10.01
9 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
10 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
OFUEL DROPS
1 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
2 126.2461 .11531E-08 4339. .0377 1102.51 .153E+09 .962E+00 -.192E-01 6.60
3 434.6171 .47003E-07 3772. .0502 1102.97 .416E+08 .577E+00 -.417E-01 7.93
4 832.9493 .34372E-06 3351. .0595 1084.76 .113E+08 .164E+00 -.270E-01 9.27
5 1543.3223 .27169E-05 2805. .0716 900.46 .170E+07 .537E-02 -.132E-02 11.23
6 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
7 94.5034 .48396E-09 4464. .0349 1102.24 .198E+09 .979E+00 -.153E-01 6.46
8 458.3575 .55186E-07 3740. .0509 1102.52 .406E+08 .516E+00 -.443E-01 7.80
9 1100.0587 .88095E-06 3094. .0652 1012.82 .508E+07 .334E-01 -.844E-02 9.54
10 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00

OXIDIZER FUEL TOTAL COMBUST.
BURNING RATE PARAMETER .010592 .013663 .024255 .059277
DRAG PARAMETER .08 .20 .28

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SCRIPT J .31283E-06
OINTEGRATION STEP= .0021
1 CASE3 LOX/RP1 TRW 50K ENGINE

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OX=-11.030 U= 6226.1 T=6059. TO=6072. P= 230.60 PO= 233.23 O/F= .3869E+01 MACH= .137 AREA= 452.39 DADX= .000E+00
OVAPORIZED FRACTION O .950986 F .651378 BOTH .868904 COMB .785200 SOUND SPEED= .456E+05
VAPORIZATION RATE/IN O .003675 F .012127 BOTH .005991 COMB .014619
0 D(MICR) MASS(LB) V(IN/SEC) U-V/A TEMP NUMBER (MI-M)/MI (DM/DX)/MI RAD POSIT.
OXIDIZER DROPS
1 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
2 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
3 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
4 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
5 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
6 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
7 190.1831 .73919E-08 4000. .0488 228.67 .133E+09 .920E+00 -.164E-01 8.50
8 562.4684 .19121E-06 3402. .0620 228.68 .263E+08 .590E+00 -.204E-01 10.37
9 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
10 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
OFUEL DROPS
1 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
2 82.9718 .32780E-09 4822. .0308 1101.87 .153E+09 .989E+00 -.867E-02 6.75
3 407.0829 .38621E-07 4090. .0469 1102.99 .416E+08 .653E+00 -.341E-01 8.15
4 818.4876 .32169E-06 3654. .0564 1091.38 .113E+08 .218E+00 -.264E-01 9.58
5 1553.1606 .27088E-05 3078. .0691 927.01 .170E+07 .834E-02 -.163E-02 11.68
6 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00
7 46.8584 .59150E-10 5243. .0215 1101.03 .198E+09 .997E+00 -.394E-02 6.60
8 431.4406 .45994E-07 4057. .0476 1102.82 .406E+08 .596E+00 -.367E-01 8.05
9 1102.9844 .86419E-06 3386. .0623 1035.58 .508E+07 .518E-01 -.984E-02 9.93
10 .0000 .00000E+00 0. .0000 .00 .000E+00 .100E+01 .000E+00 .00

OXIDIZER FUEL TOTAL COMBUST.
BURNING RATE PARAMETER .008520 .010608 .019128 .045703
DRAG PARAMETER .06 .17 .23

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SCRIPT J .31460E-06
OINTEGRATION STEP= .0445
1 CASE3 LOX/RP1 TRW 50K ENGINE

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OX=-9.030 U= 6366.6 T=6066. TO=6079. P= 230.48 PO= 233.19 O/F= .3770E+01 MACH= .139 AREA= 452.39 DADX= .000E+00
OVAPORIZED FRACTION O .957612 F .673099 BOTH .879665 COMB .811383 SOUND SPEED= .458E+05
VAPORIZATION RATE/IN O .002990 F .009852 BOTH .004870 COMB .011876
0 D(MICR) MASS(LB) V(IN/SEC) U-V/A TEMP NUMBER (MI-M)/MI (DM/DX)/MI RAD POSIT.
OXIDIZER DROPS

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case3.out

1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
6	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
7	164.5777	.47903E-08	4294.	.0452	228.66	.133E+09	.948E+00	-.121E-01	8.71
8	544.4733	.17346E-06	3651.	.0593	228.65	.263E+08	.628E+00	-.178E-01	10.69
9	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
10	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00

OFUEL DROPS

1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	37.6083	.30624E-10	5616.	.0164	1100.35	.153E+09	.999E+00	-.190E-02	6.86
3	381.1549	.31710E-07	4358.	.0438	1102.88	.416E+08	.715E+00	-.283E-01	8.35
4	802.3401	.30056E-06	3910.	.0536	1095.28	.113E+08	.269E+00	-.250E-01	9.86
5	1561.4137	.26992E-05	3314.	.0666	949.94	.170E+07	.118E-01	-.186E-02	12.08
6	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
7	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
8	406.0229	.38334E-07	4323.	.0446	1102.83	.406E+08	.664E+00	-.308E-01	8.28
9	1102.4861	.84542E-06	3635.	.0596	1052.42	.508E+07	.724E-01	-.107E-01	10.28
10	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00

	OXIDIZER	FUEL	TOTAL	COMBUST.
BURNING RATE PARAMETER	.006967	.008661	.015629	.037127
DRAG PARAMETER	.05	.14	.19	

SCRIPT J .31590E-06

OINTEGRATION STEP= .0879

OK. DROP GROUP 7 IS BOILING

1 CASE3 LOX/RP1 TRW 50K ENGINE

OX= -7.169 U= 6476.3 T=6071. TO=6084. P= 230.38 PO= 233.17 O/F= .3696E+01 MACH= .141 AREA= 452.39 DADX= .000E+00
 OVAPORIZED FRACTION O .962692 F .690292 BOTH .888064 COMB .832109 SOUND SPEED= .460E+05
 VAPORIZATION RATE/IN O .002875 F .008772 BOTH .004491 COMB .010574

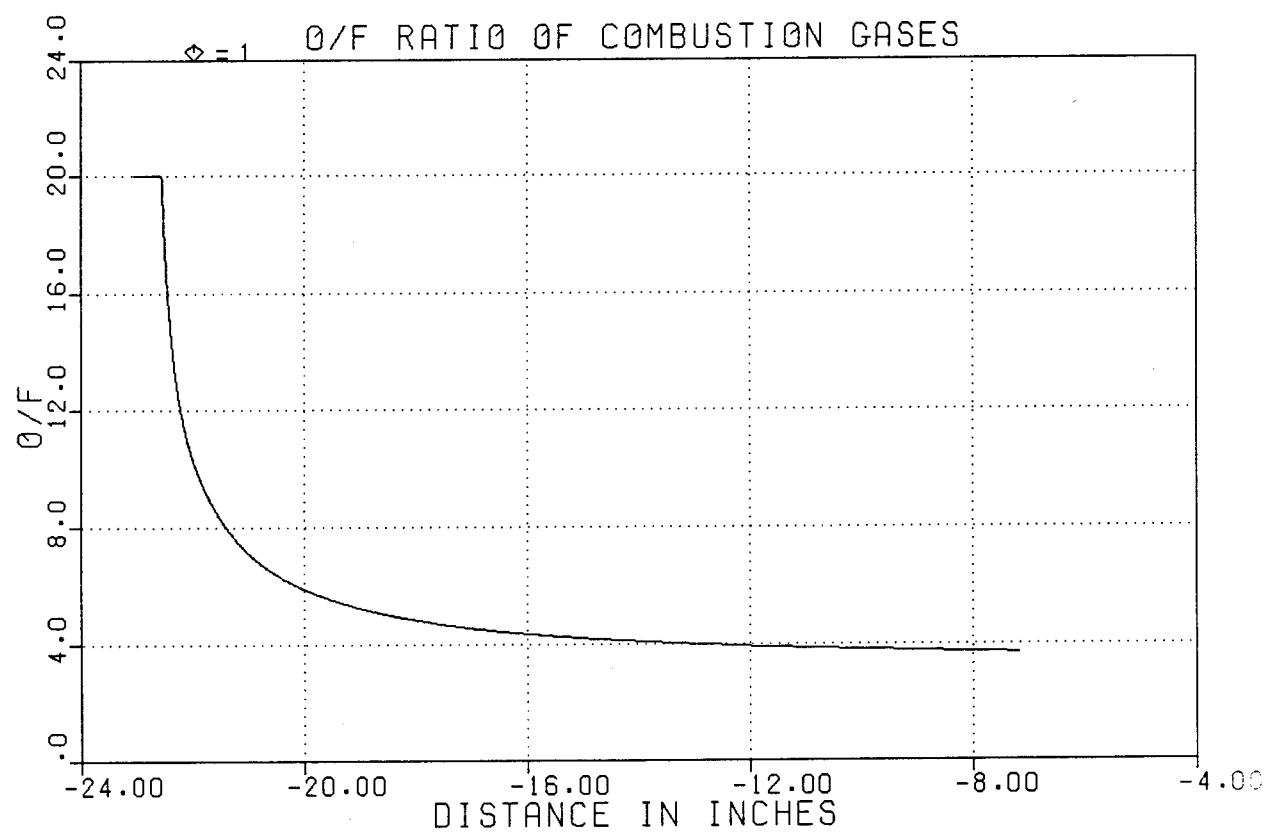
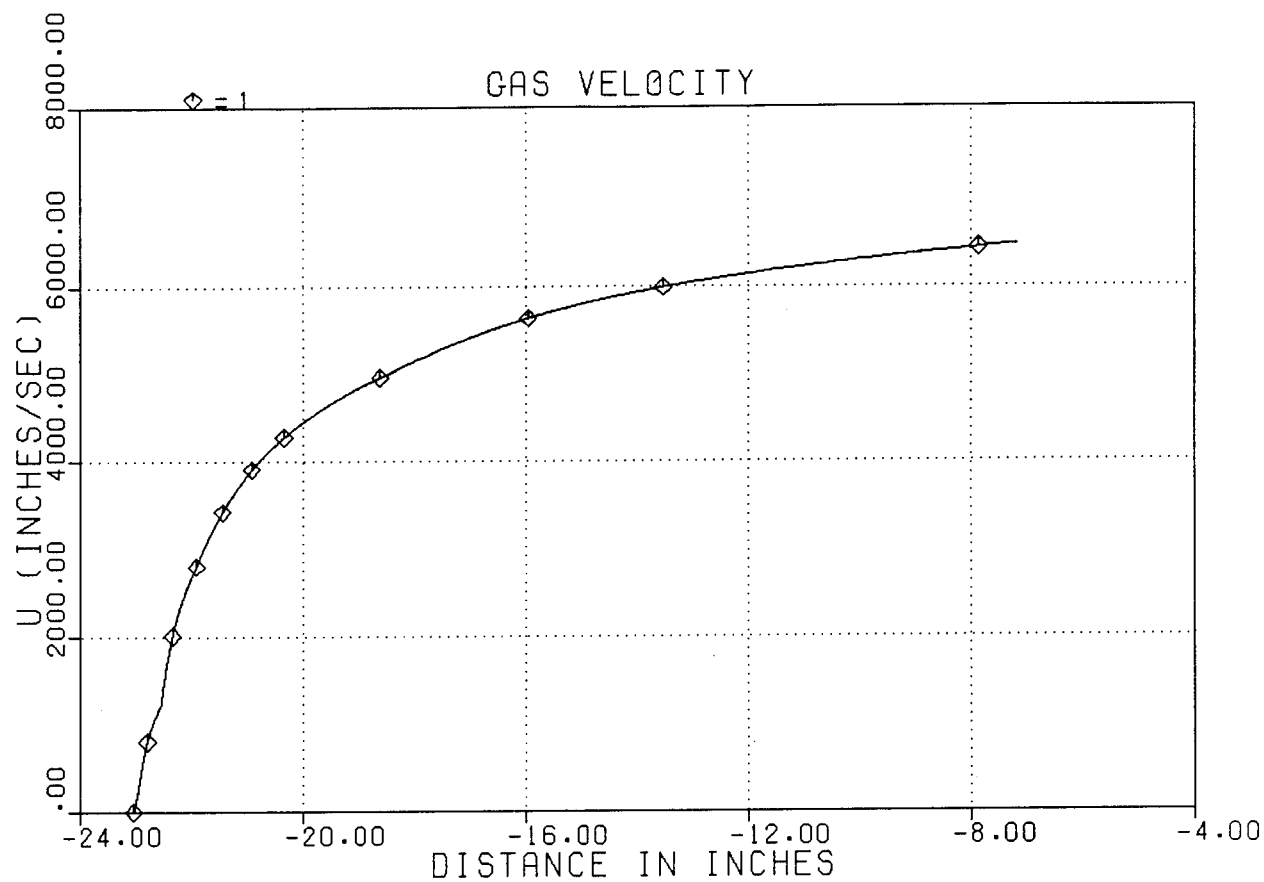
	D(MICR)	MASS(LB)	V(IN/SEC)	U-V/A	TEMP	NUMBER	(MI-M)/MI	(DM/DX)/MI	RAD POSIT.
OXIDIZER DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
4	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
5	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
6	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
7	141.0202	.29904E-08	4539.	.0421	230.09	.133E+09	.968E+00	-.129E-01	8.90
8	528.7377	.15887E-06	3855.	.0570	228.63	.263E+08	.659E+00	-.159E-01	10.98
9	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
10	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
OFUEL DROPS									
1	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
2	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
3	358.1183	.26308E-07	4573.	.0414	1102.74	.416E+08	.763E+00	-.240E-01	8.53
4	786.7512	.28202E-06	4116.	.0513	1097.57	.113E+08	.314E+00	-.235E-01	10.10
5	1568.9893	.26890E-05	3508.	.0645	968.66	.170E+07	.156E-01	-.225E-02	12.43
6	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
7	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00
8	383.4424	.32293E-07	4538.	.0421	1102.74	.406E+08	.717E+00	-.264E-01	8.47
9	1100.9216	.82671E-06	3838.	.0574	1064.44	.508E+07	.930E-01	-.116E-01	10.59
10	.0000	.00000E+00	0.	.0000	.00	.000E+00	.100E+01	.000E+00	.00

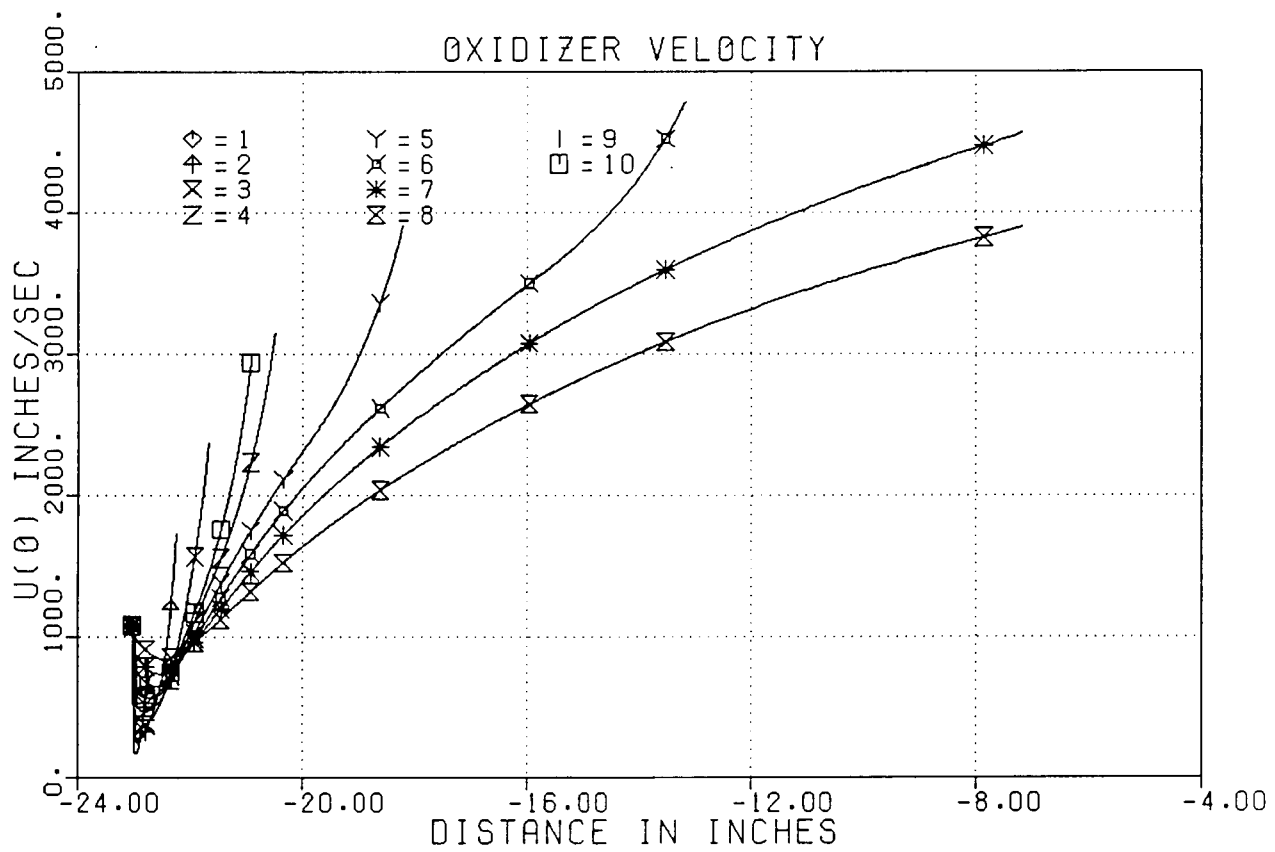
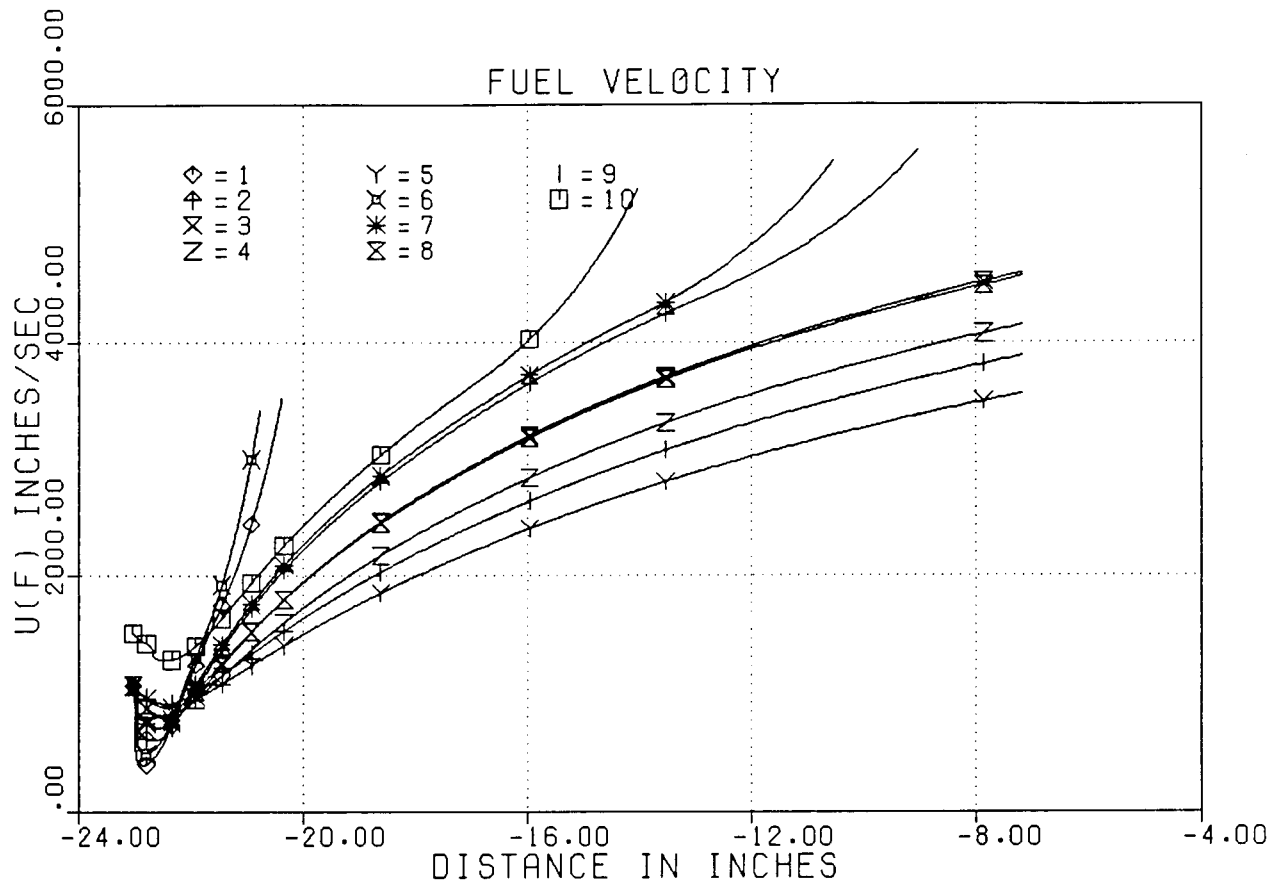
	OXIDIZER	FUEL	TOTAL	COMBUST.
BURNING RATE PARAMETER	.006725	.007742	.014467	.033057
DRAG PARAMETER	.04	.13	.17	

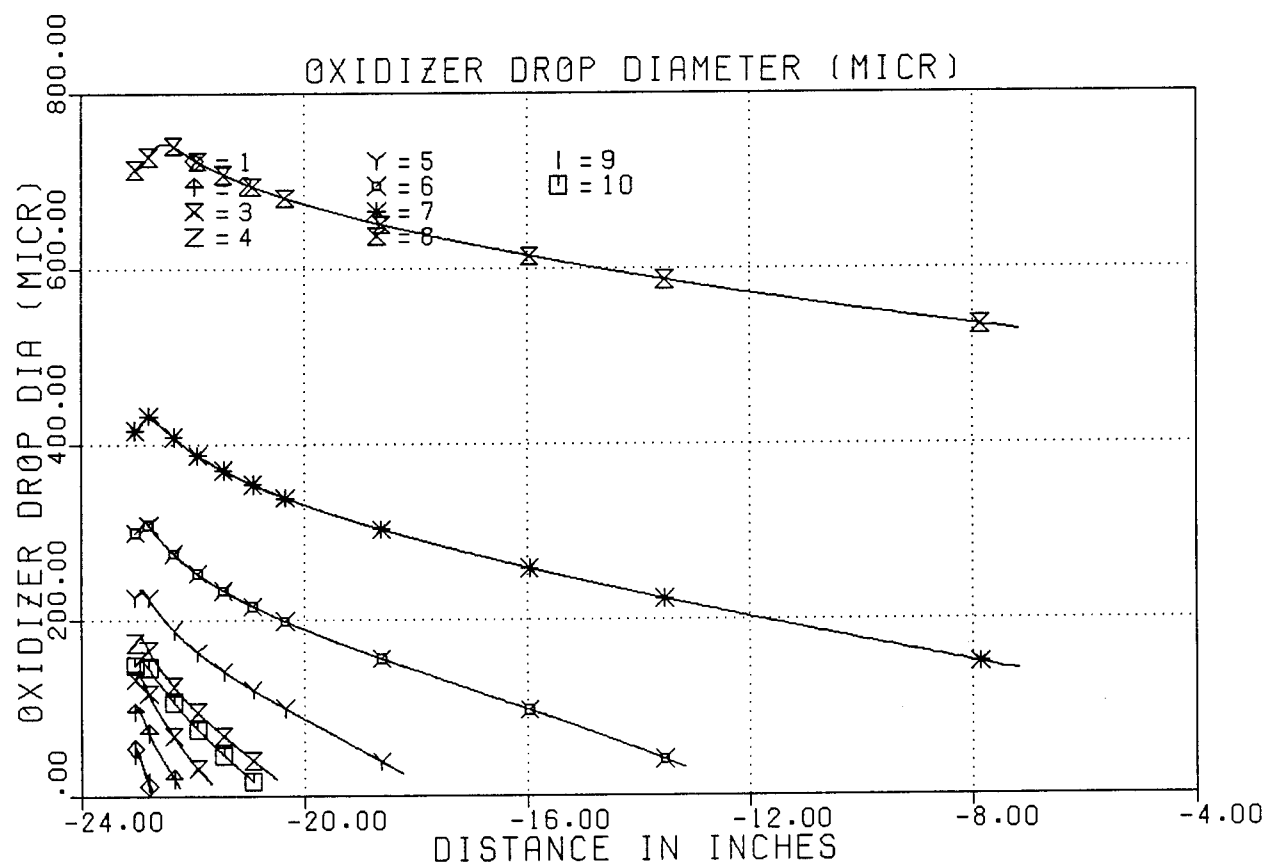
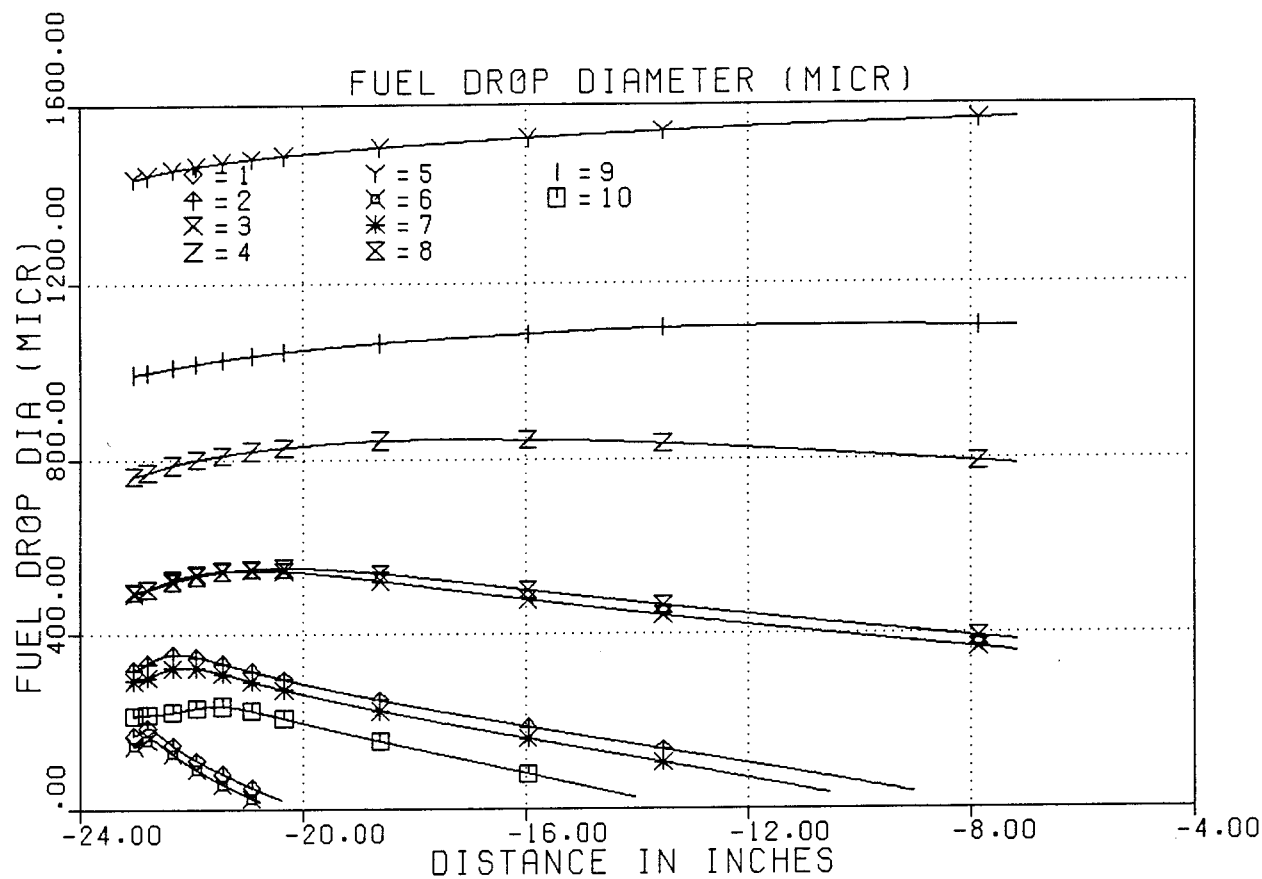
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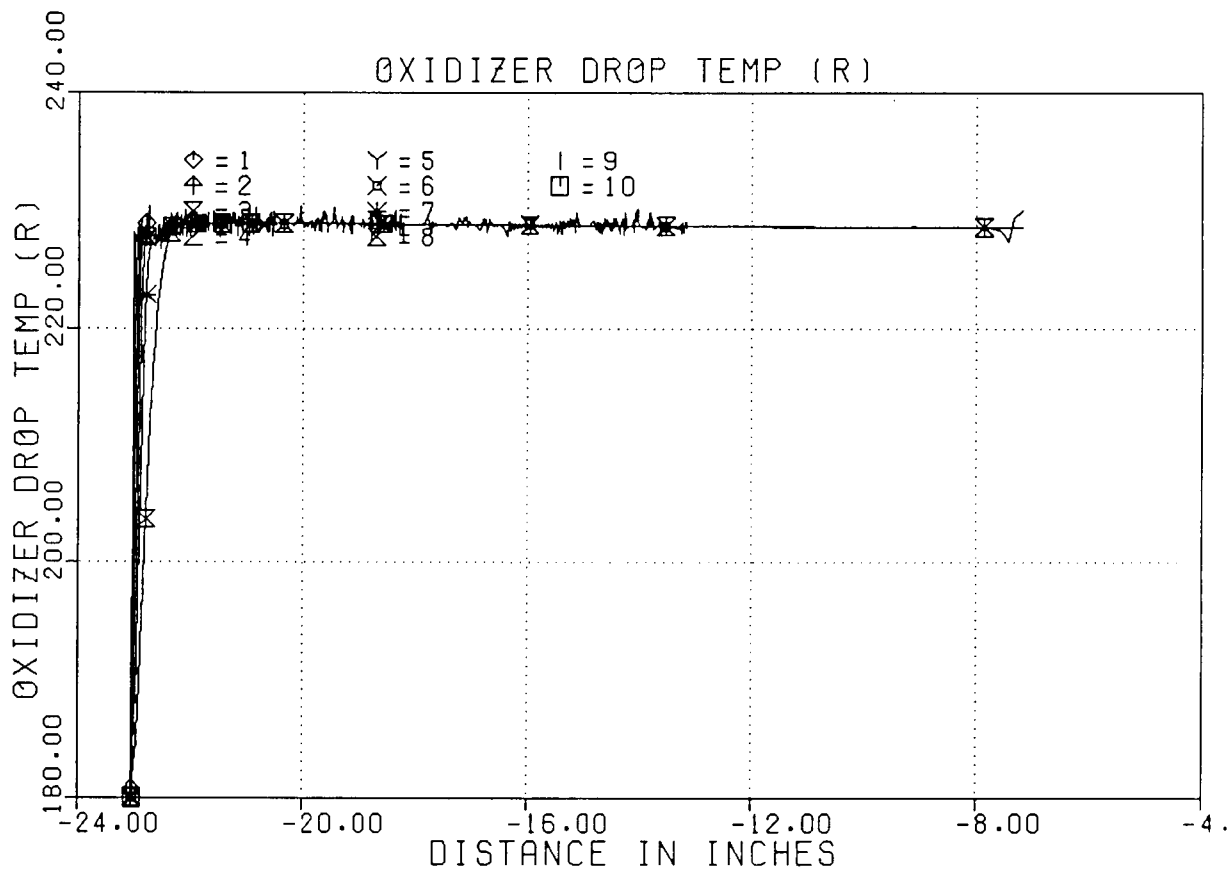
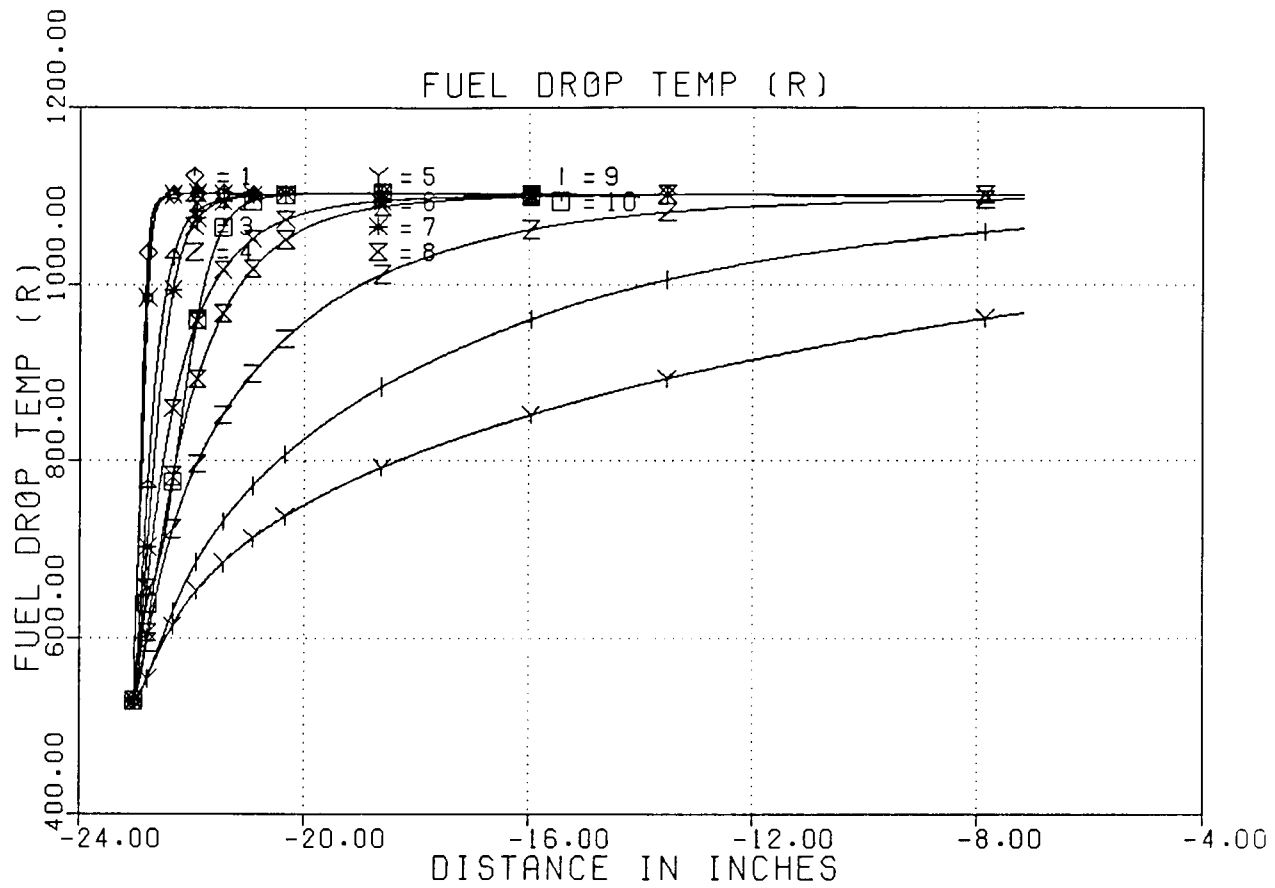
OINTEGRATION STEP= .1694

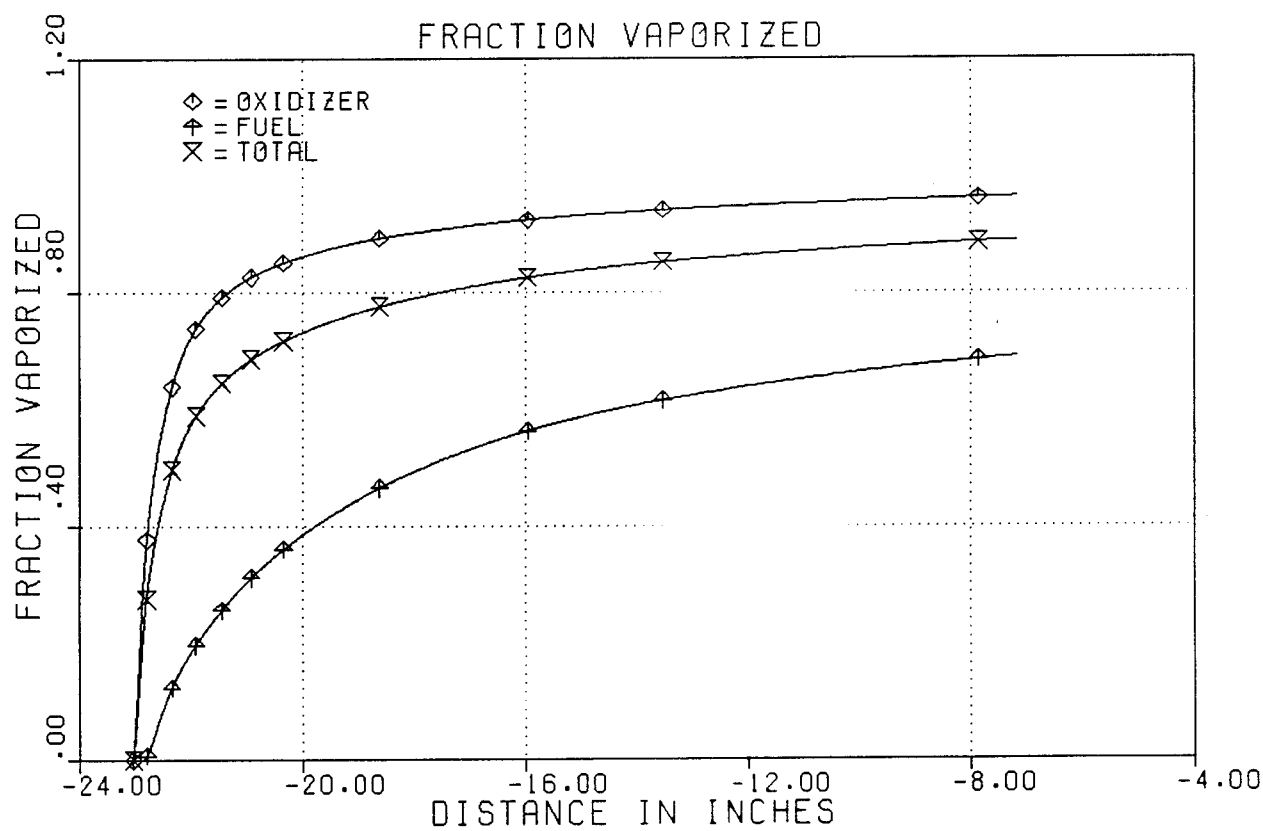
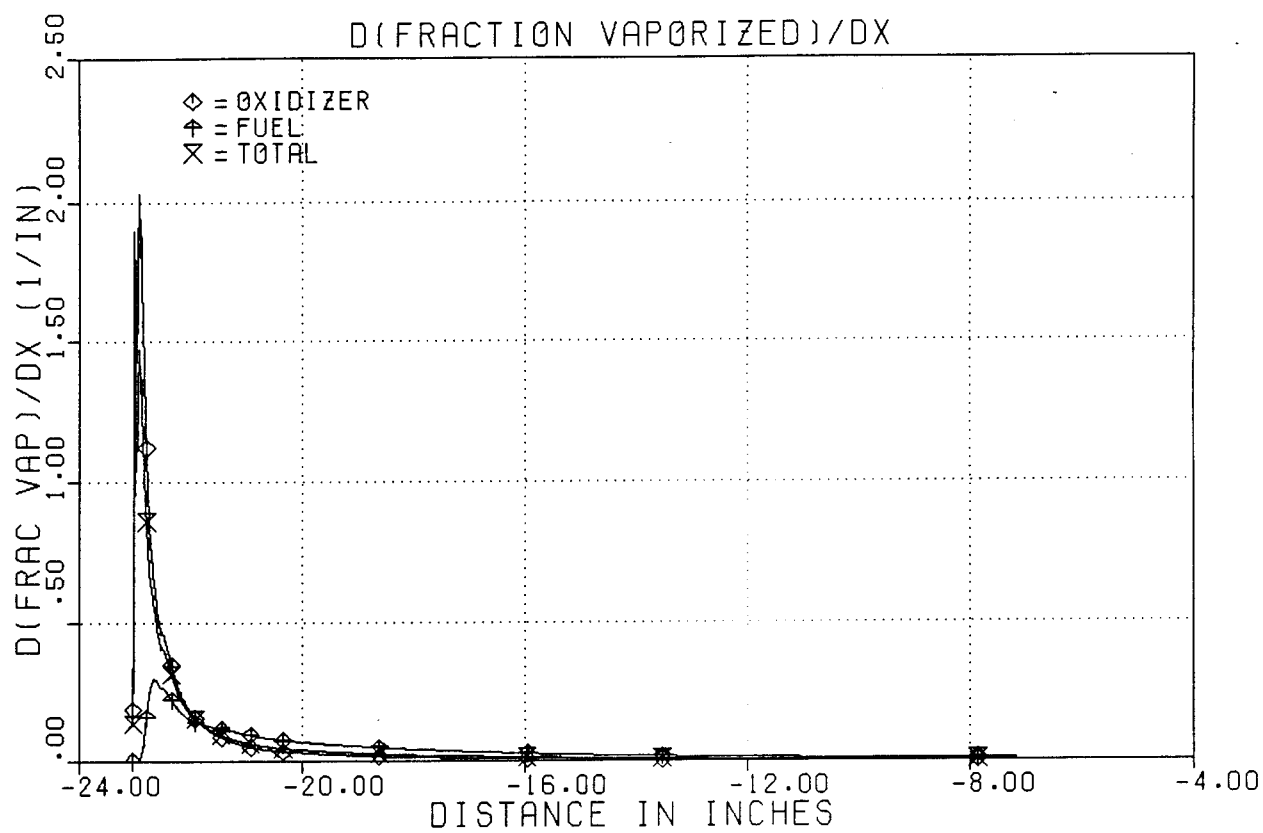
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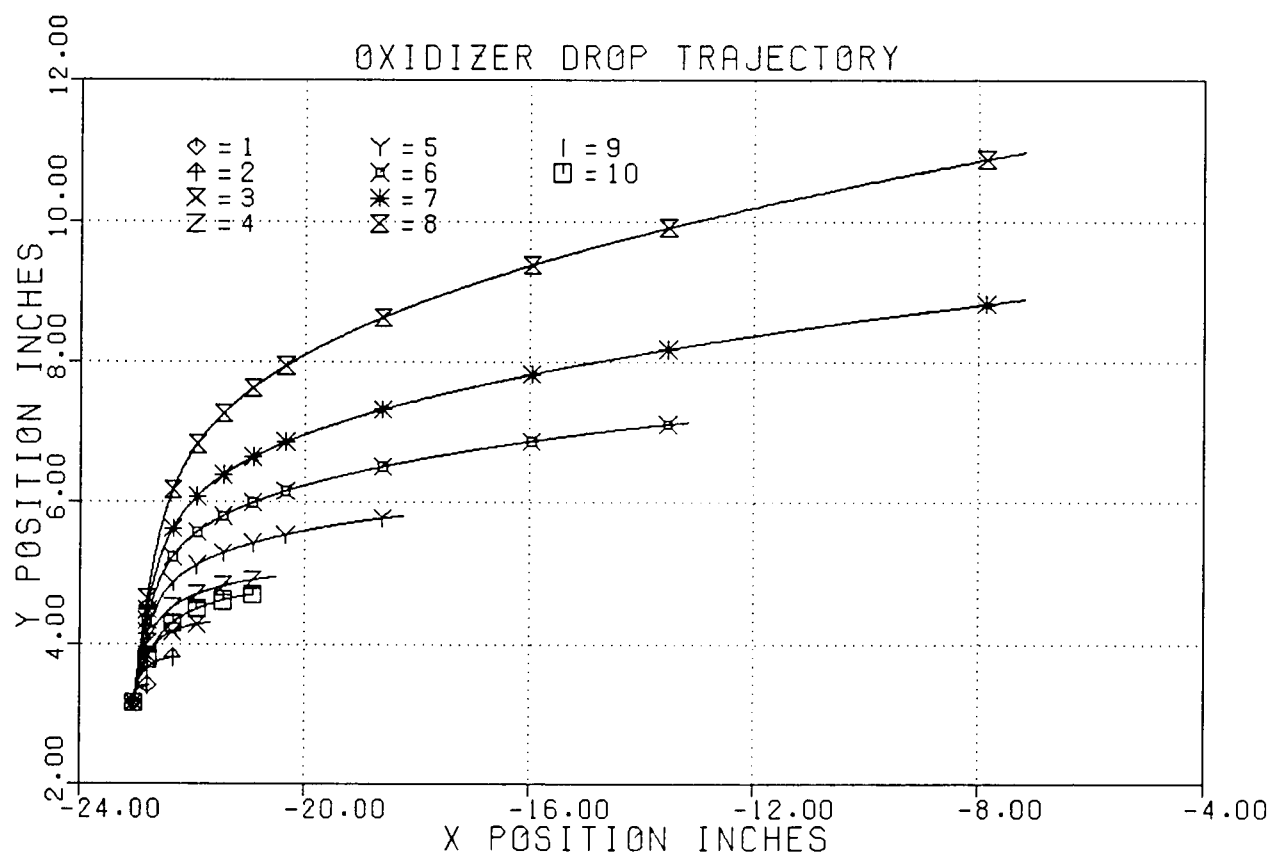
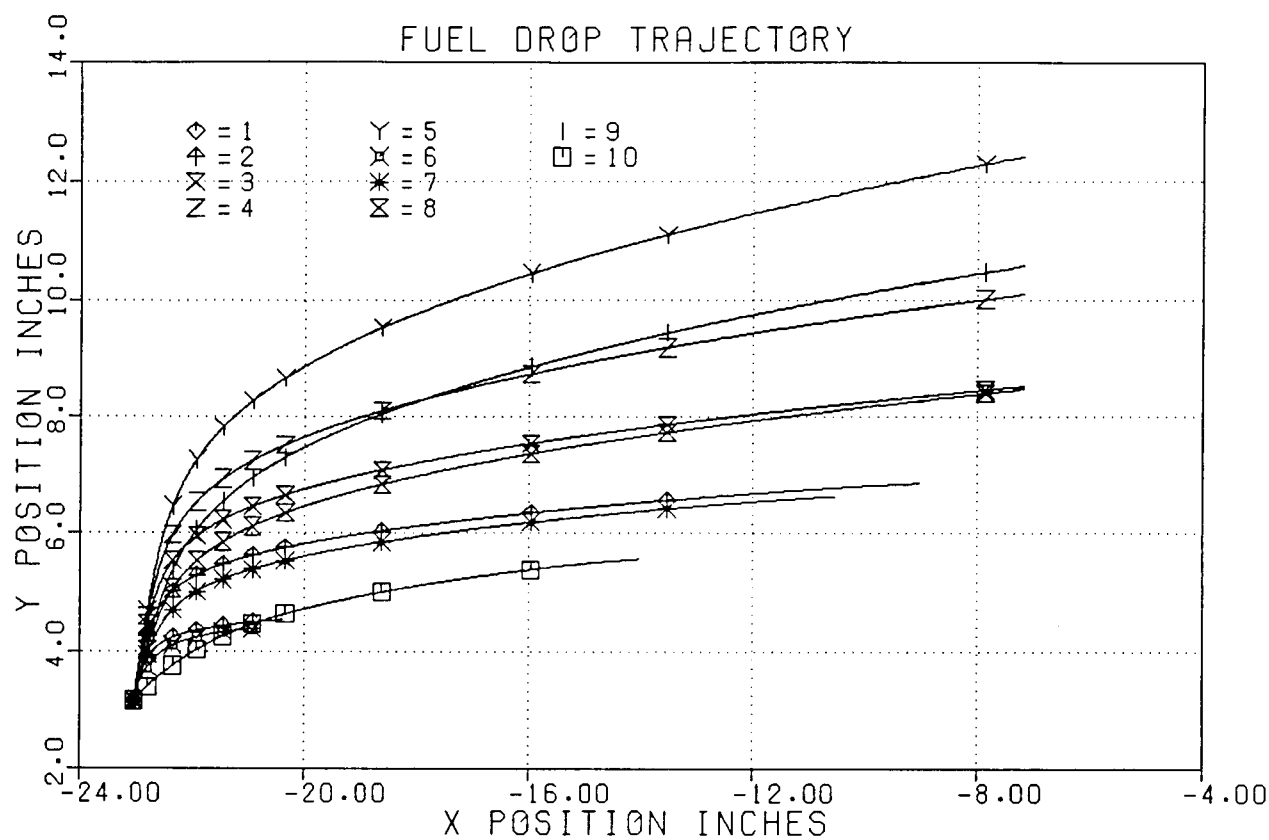












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REFERENCES

1. Priem, R.J., and Heidmann, M.F., "Propellant Vaporization as a Design Criterion for Rocket-Engine Combustion Chambers," NASA TR R-67, 1960.
2. Kawasaki, A.H., Coats, D.E., and Berker, D.R., "A Two-Phase, Two-Dimensional Reacting Parabolized Navier Stokes Flow Solver for the Prediction of Solid Rocket Motor Flowfield," AIAA 92-3600, AIAA/SAE/ASME/ASEE 28th Joint Propulsion Conference, Nashville, Tennessee, 1992.
3. Nickerson, G.R., Berker, D.B., Coats, D.E., Dunn, S.S., and Johnson, C.W., *Two-Dimensional Kinetics (TDK) Nozzle Performance Computer Program Volume III, User's Manual*, Software and Engineering Associates, Inc., NAS8-39048, March 1993.
4. Nickerson, G.R., and Nguyen, T.K., "Computer Program for the Prediction of Combustion Instability using a Nonlinear Bipropellant Vaporization Model," SEA Inc., Report No. SN75-01, November 1984.
5. Priem, R.J., and Guentert, D.C., "Combustion Instability Limits Determined by a Non-linear Theory and a One-Dimensional Model," Lewis Research Center, Cleveland, Ohio. NASA TN-1409, October 1962.
6. Bird, R.B., Stewart, W.E., and Lightfoot, E.N., "Transport Phenomena," John Wiley & Sons, Inc. New York, 1960.
7. TRW Systems Group, "Characteristics of the TRW Lunar Module Descent Engine," Volume I (revised), TRW No. 10827-6119-T000, January 1969.

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APPENDIX A

Listing of Propellant Properties Input Data

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SINPOT
PCRTT= 1470, 1696,
NAMES='N2O4', 'AEROZINE 50',
NPRES= 3,
NSP=12,
SPNAME= '      '      '      '      '      '      '      '      '      '      '
          H'  '      H2'  '      H2O'  '      N2'  '      CO'  '      CO2'  '
          HO'  '      O2'  '      NO'  '      O'  '      CH4'  '      H3N'  '
WM(1)=    1.00,    2.00,    18.00,    28.00,    28.00,    44.00,    17.00,    32.00,    30.00,    16.00,    16.00,    17.00,
EPSI(1,1)= 37.000, 59.700,809.000, 71.400, 91.700,195.000, 79.800,106.700,116.700,106.700,148.600,558.000,
SIGMA(1,1)= 2.7100, 2.8300, 2.6400, 3.8000, 3.6900, 3.9400, 3.1500, 3.4700, 3.4900, 3.0500, 3.7600, 2.9000,
SIGOF=    3.9690,    4.2460,    WTMOL= 46.0000,    42.0000,
PRSS=    100.000,    300.000,    1000.000,    EPSOF= 331.900,    467.400,
NR= 9,
R(1)=      15.000, 10.000, 5.000, 2.000, 1.000, 0.500, 0.200, 0.100, 0.066,
YSP(1, 1,1)= 0.0, 0.0, 0.0, 0.0240, 0.0070,
YSP(1, 2,1)= 0.0, 0.0, 0.0, 0.0710, 0.3330, 0.5390, 0.5810, 0.5810, 0.5760,
YSP(1, 3,1)= 0.1170, 0.1670, 0.2760, 0.3690, 0.2190, 0.0450, 0.0120, 0.0110, 0.0100,
YSP(1, 4,1)= 0.3430, 0.3450, 0.3430, 0.3320, 0.3020, 0.2680, 0.2800, 0.2910, 0.2960,
YSP(1, 5,1)= 0.0, 0.0, 0.0030, 0.0710, 0.1280, 0.1430, 0.0780, 0.0370, 0.0240,
YSP(1, 6,1)= 0.0290, 0.0430, 0.0700, 0.0490, 0.0140, 0.0040,
YSP(1, 7,1)= 0.0, 0.0, 0.0240, 0.0440,
YSP(1, 8,1)= 0.5070, 0.4400, 0.2540, 0.0180,
YSP(1, 9,1)= 0.0, 0.0060, 0.0220, 0.0110,
YSP(1,10,1)= 0.0, 0.0, 0.0050, 0.0090,
YSP(1,11,1)= 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0470, 0.0780, 0.0920,
YSP(1, 1,2)= 0.0, 0.0, 0.0, 0.0180, 0.0030,
YSP(1, 2,2)= 0.0, 0.0, 0.0, 0.0670, 0.3330, 0.5380, 0.5460, 0.5390, 0.5340,
YSP(1, 3,2)= 0.1170, 0.1670, 0.2790, 0.3840, 0.2210, 0.0450, 0.0140, 0.0130, 0.0110,
YSP(1, 4,2)= 0.3430, 0.3450, 0.3410, 0.3350, 0.3000, 0.2680, 0.2870, 0.3000, 0.3060,
YSP(1, 5,2)= 0.0, 0.0, 0.0030, 0.0690, 0.1280, 0.1430, 0.0780, 0.0370, 0.0240,
YSP(1, 6,2)= 0.0290, 0.0430, 0.0700, 0.0510, 0.0140, 0.0, 0.0010,
YSP(1, 7,2)= 0.0, 0.0, 0.0190, 0.0420,
YSP(1, 8,2)= 0.5070, 0.4400, 0.2550, 0.0160,
YSP(1, 9,2)= 0.0, 0.0060, 0.0240, 0.0110,
YSP(1,10,2)= 0.0, 0.0, 0.0030, 0.0070,
YSP(1,11,2)= 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0720, 0.1090, 0.1250,
YSP(1, 1,3)= 0.0, 0.0, 0.0, 0.0140, 0.0020,
YSP(1, 2,3)= 0.0, 0.0, 0.0, 0.0610, 0.3350, 0.5300, 0.4970, 0.4830, 0.4750,
YSP(1, 3,3)= 0.1170, 0.1700, 0.2830, 0.3980, 0.2210, 0.0490, 0.0190, 0.0150, 0.0120,
YSP(1, 4,3)= 0.3430, 0.3450, 0.3420, 0.3390, 0.3020, 0.2690, 0.2970, 0.3120, 0.3180,
YSP(1, 5,3)= 0.0, 0.0, 0.0, 0.0680, 0.1290, 0.1400, 0.0760, 0.0370, 0.0250,
YSP(1, 6,3)= 0.0290, 0.0430, 0.0730, 0.0570, 0.0140, 0.0040, 0.0010,
YSP(1, 7,3)= 0.0, 0.0, 0.0160, 0.0360,
YSP(1, 8,3)= 0.5070, 0.4400, 0.2550, 0.0110,
YSP(1, 9,3)= 0.0, 0.0060, 0.0240, 0.0110,
YSP(1,10,3)= 0.0, 0.0, 0.0, 0.0050,
YSP(1,11,3)= 0.0, 0.0, 0.0, 0.0, 0.0, 0.0040, 0.1060, 0.1500, 0.1680,
YSP(1,12,3)= 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0010, 0.0010, 0.0010,
WMTAB(1,1)= 29.3400,28.7700,27.0300,22.1100,17.2300,13.6100,12.8000,12.7700,12.7700,
WMTAB(1,2)= 29.3400,28.7700,27.1100,22.3400,17.2500,13.6300,13.1500,13.1600,13.1700,
WMTAB(1,3)= 29.3400,28.7700,27.1800,22.5900,17.2700,13.7400,13.6200,13.7600,13.7000,
TCL(1,1)= 2355.00,3289.00,4743.00,5630.00,4541.00,2747.00,2099.00,1982.00,1958.00,
TCL(1,2)= 2485.00,3290.00,4806.00,5841.00,4570.00,2754.00,2230.00,2126.00,2090.00,
TCL(1,3)= 2486.00,3292.00,4860.00,6064.00,4590.00,2801.00,2392.00,2290.00,2250.00,
FGAMT(1)= 1.286, 1.264, 1.232, 1.223, 1.258, 1.320, 1.295, 1.278, 1.272,
NT= 6,
TTAB(1)= 540.00,1080.00,1980.00,3060.00,4860.00,7020.00,
VSP(1,1)= 0.4190, 0.6580, 0.9760, 1.2920, 1.7140, 2.2070,
VSP(1,2)= 0.5000, 0.7950, 1.1790, 1.5640, 2.1080, 2.6720,
VSP(1,3)= 0.6140, 1.2030, 2.2020, 3.2520, 4.6930, 6.1210,
VSP(1,4)= 0.9950, 1.5980, 2.3670, 3.1460, 4.2420, 5.3780,
VSP(1,5)= 0.9940, 1.6230, 2.4160, 3.2090, 4.3320, 5.4930,
VSP(1,6)= 0.8510, 1.5200, 2.3500, 3.1490, 4.2450, 5.4020,
VSP(1,7)= 1.1020, 1.7810, 2.6400, 3.5110, 4.7370, 6.0040,
VSP(1,8)= 1.1560, 1.9120, 2.8630, 3.7960, 5.1300, 6.5060,
VSP(1,9)= 1.0750, 1.7950, 2.6970, 3.5710, 4.8330, 6.1300,
VSP(1,10)= 1.0560, 1.7470, 2.6160, 3.4680, 4.6870, 5.9440,
VSP(1,11)= 0.6280, 1.0780, 1.6370, 2.1770, 2.9420, 3.7350,
VSP(1,12)= 0.5830, 1.1730, 2.0620, 2.9320, 4.1090, 5.2830,
CPTAB(1,1)= 2.500, 2.500, 2.500, 2.500, 2.500, 2.500,
CPTAB(1,2)= 7.000, 7.050, 7.350, 7.990, 8.620, 9.110,
CPTAB(1,3)= 8.080, 8.730, 10.220, 11.750, 13.200, 14.010,
CPTAB(1,4)= 7.000, 7.240, 8.000, 8.510, 8.850, 8.990,
CPTAB(1,5)= 7.000, 7.300, 8.100, 8.600, 8.910, 9.050,
CPTAB(1,6)= 8.940, 11.350, 13.290, 14.340, 14.830, 15.130,
CPTAB(1,7)= 7.000, 7.040, 7.460, 8.090, 8.730, 9.100,
CPTAB(1,8)= 7.070, 7.700, 8.470, 8.890, 9.440, 9.920,
CPTAB(1,9)= 7.170, 7.500, 8.280, 8.690, 8.970, 9.120,
CPTAB(1,10)= 5.260, 5.090, 5.020, 5.010, 5.020, 5.120,
CPTAB(1,11)= 8.570, 12.560, 18.150, 21.700, 24.000, 25.000,
CPTAB(1,12)= 8.550, 10.720, 14.000, 16.530, 18.430, 19.350,
NTL= 10, 14, NTFILM= 7, 6,
TLI(1,1)= 400.00, 440.00, 480.00, 520.00, 560.00, 600.00, 640.00, 680.00, 720.00, 760.00,
TLI(1,2)= 500.00, 550.00, 600.00, 650.00, 700.00, 750.00, 800.00, 850.00, 900.00, 950.00,1000.00,1050.00,1080.00,1090.00,
PV(1,1)= 0.270, 0.850, 3.940, 11.800, 30.000, 80.000,180.000,330.000,660.000,1200.00,
PV(1,2)= 0.600, 4.400, 10.800, 23.000, 48.000, 92.000,162.000,272.000,420.000,640.000,920.000,1300.00,1580.00,1610.00,
RHOL(1,1)= .058000,.055600,.054100,.052700,.050850,.048700,.046300,.043500,.039350,.032400,
RHOL(1,2)= .033100,.032100,.031300,.030300,.029400,.028300,.027200,.025900,.024500,.022900,.020800,.018500,.016500,.015900,
CP(1,1)= 0.35000,0.35000,0.35300,0.37200,0.38800,0.41400,0.46400,0.54300,0.70000,0.87000,
CP(1,2)= 0.68400,0.69600,0.71100,0.72500,0.74100,0.76000,0.77800,0.79800,0.81800,0.83900,0.86100,0.88400,0.89600,0.90300,
LAM(1,1)= 435.000,430.000,422.000,412.000,403.000,392.000,379.000,365.000,346.000,315.000,
LAM(1,2)= 442.000,429.000,414.000,397.000,380.000,361.000,339.000,316.000,289.000,257.000,219.000,163.000,107.000, 69.000,
TFILM(1,1)= 400.00, 600.00,1000.00,1600.00,2400.00,3200.00,4000.00,
TFILM(1,2)= 400.00, 800.00,1200.00,2000.00,2800.00,4000.00,
VVIS(1,1)= 0.62400,0.92000,1.57000,2.34000,3.21000,3.91000,4.57000,
VVIS(1,2)= 0.33400,0.58400,0.80000,1.33000,1.75000,2.25000,
KVAP(1,1)= 0.094, 0.224, 0.485, 0.875, 1.390, 1.910, 2.440,
KVAP(1,2)= 0.100, 0.210, 0.584, 1.180, 1.620, 2.050,
CFVAP(1,1)= 0.231, 0.238, 0.253, 0.269, 0.286, 0.297, 0.300,
CFVAP(1,2)= 0.450, 0.560, 0.655, 0.798, 0.853, 0.876,
$END
```

F-1.RP1

```

$INPUT
PCRT(1)= 730.6, 315.0,
FLAMEF= 2, TFLAME=6458.,
NAMES='LOX','RP-1',
NSP= 6,
SPNAME= ' CH4',' CO',' CO2',' H2',' H2O',' O2',
WM(1)= 16.04, 28.01, 44.01, 2.02, 18.02, 32.00,
EPSI(1,1)= 148.600, 91.700, 195.200, 59.700, 809.100, 106.70,
SIGMA(1,1)= 3.7580, 3.6900, 3.9410, 2.8270, 2.6410, 3.47,
SIGOF= 3.4670, 7.5620, WTMOL= 32.0000, 172.000,
EPSOF= 106.700, 521.000,
NPRES= 3,
PRSS= 500.000, 1000.000, 1500.000,
NR= 13,
R(1)= 0.30, 0.60, 0.80, 1.00, 1.20, 1.50, 2.00, 2.50, 3.00,
3.50, 4.00, 7.00, 15.0,
YSP(1,1,1)= 0.59, 0.30, 0.17, 0.07, 0.00, 0.00, 0.00, 0.00, 0.00,
0.00, 0.00, 0.00, 0.00,
YSP(1,2,1)= 0.33, 0.46, 0.49, 0.51, 0.50, 0.48, 0.43, 0.32, 0.26,
0.21, 0.16, 0.04, 0.00,
YSP(1,3,1)= 0.01, 0.00, 0.00, 0.00, 0.01, 0.03, 0.08, 0.19, 0.17,
0.20, 0.22, 0.23, 0.14,
YSP(1,4,1)= 0.07, 0.24, 0.33, 0.42, 0.47, 0.36, 0.19, 0.08, 0.07,
0.04, 0.03, 0.00, 0.00,
YSP(1,5,1)= 0.00, 0.00, 0.00, 0.00, 0.00, 0.02, 0.13, 0.30, 0.41, 0.31,
0.30, 0.29, 0.23, 0.14,
YSP(1,6,1)= 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.19,
0.25, 0.30, 0.50, 0.72,
YSP(1,1,2)= 0.60, 0.31, 0.20, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00,
0.00, 0.00, 0.00, 0.00,
YSP(1,2,2)= 0.32, 0.47, 0.50, 0.51, 0.50, 0.48, 0.43, 0.32, 0.26,
0.20, 0.15, 0.03, 0.00,
YSP(1,3,2)= 0.02, 0.00, 0.00, 0.00, 0.01, 0.03, 0.08, 0.19, 0.18,
0.21, 0.23, 0.24, 0.14,
YSP(1,4,2)= 0.06, 0.22, 0.30, 0.41, 0.47, 0.36, 0.19, 0.08, 0.05,
0.04, 0.02, 0.00, 0.00,
YSP(1,5,2)= 0.00, 0.00, 0.00, 0.00, 0.00, 0.02, 0.13, 0.30, 0.32, 0.32,
0.31, 0.30, 0.23, 0.14,
YSP(1,6,2)= 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.19,
0.24, 0.30, 0.50, 0.72,
YSP(1,1,3)= 0.60, 0.33, 0.21, 0.08, 0.01, 0.00, 0.00, 0.00, 0.00,
0.00, 0.00, 0.00, 0.00,
YSP(1,2,3)= 0.32, 0.47, 0.50, 0.51, 0.50, 0.48, 0.43, 0.32, 0.25,
0.20, 0.15, 0.03, 0.00,
YSP(1,3,3)= 0.02, 0.00, 0.00, 0.00, 0.01, 0.03, 0.08, 0.19, 0.19,
0.22, 0.24, 0.24, 0.14,
YSP(1,4,3)= 0.06, 0.20, 0.29, 0.41, 0.46, 0.36, 0.19, 0.08, 0.05,
0.03, 0.02, 0.00, 0.00,
YSP(1,5,3)= 0.00, 0.00, 0.00, 0.00, 0.00, 0.02, 0.13, 0.30, 0.41, 0.33,
0.31, 0.30, 0.23, 0.14,
YSP(1,6,3)= 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.18,
0.24, 0.29, 0.50, 0.72,
WMTAB(1,1)= 24.7, 19.7, 17.8, 16.3, 15.6, 17.7, 20.7, 22.9, 24.5,
25.6, 26.6, 30.0, 31.7,
WMTAB(1,2)= 25.1, 20.0, 18.1, 16.4, 15.7, 17.7, 21.3, 23.1, 24.7,
25.9, 26.9, 30.1, 31.8,
WMTAB(1,3)= 25.2, 20.2, 18.2, 16.4, 15.8, 17.7, 21.3, 23.2, 24.8,
26.1, 27.0, 30.3, 31.8,
TC1(1,1)= 1910, 2465, 2733, 2894, 3190, 4539, 5952, 6417, 6486,
6444, 6365, 5729, 3923,
TC1(1,2)= 1948, 2531, 2809, 2931, 3213, 4548, 6048, 6592, 6679,
6635, 6548, 5842, 3928,
TC1(1,3)= 1971, 2569, 2851, 2961, 3239, 4552, 6098, 6694, 6794,
6750, 6657, 5906, 3930,
FGANT(1)= 1.12, 1.16, 1.18, 1.25, 1.30, 1.25, 1.22, 1.21, 1.21,
1.21, 1.20, 1.21, 1.24,
NT= 6,
TTAB(1)= 540.00,1080.00,1980.00,3060.00,4860.00,7020.00,
VSP(1,1)= 0.6277, 1.0780, 1.6370, 2.1770, 2.9420, 3.7350,
VSP(1,2)= 0.9939, 1.6230, 2.4160, 3.2090, 4.3320, 5.4930,
VSP(1,3)= 0.8512, 1.5200, 2.3500, 3.1490, 4.2450, 5.4020,
VSP(1,4)= 0.4194, 0.6580, 0.9755, 1.2918, 1.7409, 2.2070,
VSP(1,5)= 0.4995, 0.7952, 1.1790, 1.5634, 2.1077, 2.6716,
VSP(1,6)= 0.6137, 1.2033, 2.2018, 3.2518, 4.6926, 6.1211,
CPTAB(1,1)= 8.535, 12.484, 18.052, 21.580, 23.895, 24.855,
CPTAB(1,2)= 6.965, 7.275, 8.056, 8.533, 8.837, 8.986,
CPTAB(1,3)= 8.863, 11.266, 13.201, 14.145, 14.732, 15.022,
CPTAB(1,4)= 4.968, 4.968, 4.968, 4.968, 4.968, 4.968,
CPTAB(1,5)= 6.995, 7.009, 7.307, 7.907, 8.637, 9.125,
CPTAB(1,6)= 8.028, 8.680, 10.163, 11.699, 13.122, 13.933,
NTL= 0, 10, NTFILM= 0, 6,
TLI(1,2)= 460.00, 530.00, 560.00, 660.00, 760.00, 860.00,
960.00,1060.00,1160.00,1218.00,
PV(1,2)= 0.002, 0.003, 0.010, 0.210, 2.100, 11.000,
36.000,100.000,220.000,315.000,
RHOL(1,2)= .029740,.028870,.028410,.027200,.025640,.023900,
.022000,.019560,.015740,.009840,
CP(1,2)= 0.43500,0.47000,0.48500,0.54000,0.59000,0.64700,
0.70000,0.77500,0.86000,0.90100,
LAM(1,2)= 144.300,139.200,137.000,128.900,120.000,109.800,
97.770, 82.660, 60.740, 00.100,
TFILM(1,2)= 360.00, 540.00, 720.00, 900.00,1080.00,1260.00,
WVIS(1,2)= 0.15700,0.24600,0.33600,0.42000,0.48200,0.53800,
KVAP(1,2)= 0.126, 0.174, 0.278, 0.394, 0.498, 0.607,
CFVAP(1,2)= 0.275, 0.380, 0.470, 0.562, 0.650, 0.725,
SEND

```

JP4.DAT

```

$INPUT
FCRIT= 100, 315,
FLAMEF= .TRUE.,
TFLAME=4235,
NAMES='AIR', 'JP4',
NSP= 6,
SPNAME= ' CO2', ' CO', ' N2', ' H2O', ' O2', ' H2'
WM(1)= 44.01, 28.01, 28.02, 18.02, 32.00, 2.02,
EPSI(1,1)= 195.200, 91.700, 71.400, 809.100, 106.700, 59.700,
SIGMA(1,1)= 3.9410, 3.6900, 3.7980, 2.6410, 3.4670, 2.8270,
SIGOF= 3.5000, 7.5620, WTMOL= 28.5000, 172.000,
EPSOF= 300.000, 521.000,
NPRES= 1,
PRSS= 29.400,
NR=13,
R(1)= 500.000, 350.000, 250.000, 167.000, 100.000, 65.000, 48.800, 32.600, 24.400, 16.280, 14.650, 13.000, 10.600,
YSP(1, 1,1)= 0.0044, 0.0062, 0.0086, 0.0126, 0.0208, 0.0317, 0.0419, 0.0620, 0.0819, 0.1161, 0.1184, 0.1029, 0.0670,
YSP(1, 2,1)= 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0037, 0.0316, 0.0415, 0.0995,
YSP(1, 3,1)= 0.7886, 0.7879, 0.7870, 0.7855, 0.7820, 0.7782, 0.7742, 0.7665, 0.7588, 0.7419, 0.7328, 0.7141, 0.6717,
YSP(1, 4,1)= 0.0040, 0.0057, 0.0080, 0.0120, 0.0199, 0.0305, 0.0404, 0.0599, 0.0794, 0.1166, 0.1261, 0.1307, 0.1231,
YSP(1, 5,1)= 0.2029, 0.2001, 0.1964, 0.1899, 0.1769, 0.1596, 0.1434, 0.1115, 0.0799, 0.0204, 0.0065, 0.0006,
YSP(1, 6,1)= 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0008, 0.0025, 0.0099, 0.0384,
WMTAB(1,1)= 28.9640, 28.9640, 28.9630, 28.9620, 28.9610, 28.9600, 28.9580, 28.9550, 28.8650, 28.6950, 28.1890, 26.9440,
TC1(1,1)= 691.00, 756.00, 842.00, 990.00, 1274.00, 1634.00, 1954.00, 2543.00, 3083.00, 3970.00, 4136.00, 4091.00, 3731.00,
FGAMT(1)= 1.395, 1.392, 1.387, 1.377, 1.357, 1.332, 1.315, 1.289, 1.268, 1.208, 1.183, 1.223, 1.259,
NT= 5,
TTAB(1)= 540.00, 1080.00, 1980.00, 3060.00, 4320.00,
VSP(1,1)= 0.8510, 1.5200, 2.3500, 3.1490, 3.9356,
VSP(1,2)= 0.9940, 1.6200, 2.4200, 3.2100, 4.0151,
VSP(1,3)= 0.9950, 1.5950, 2.3700, 3.1400, 3.9323,
VSP(1,4)= 0.6140, 1.2000, 2.2000, 3.2500, 4.2913,
VSP(1,5)= 1.1600, 1.9100, 2.8600, 3.8000, 4.7533,
VSP(1,6)= 0.4996, 0.7953, 1.1789, 1.5637, 1.9541,
CPTAB(1,1)= 8.860, 11.270, 13.200, 14.100, 14.612,
CPTAB(1,2)= 6.970, 7.280, 8.060, 8.530, 8.776,
CPTAB(1,3)= 6.940, 7.150, 7.900, 8.400, 8.722,
CPTAB(1,4)= 8.030, 8.680, 10.160, 11.700, 12.804,
CPTAB(1,5)= 7.020, 7.670, 8.440, 8.850, 9.235,
CPTAB(1,6)= 6.955, 7.009, 7.307, 7.907, 8.460,
NTL= 11, 11, NTFLM= 8, 8,
TLI(1,2)= 460.00, 560.00, 660.00, 760.00, 860.00, 960.00, 1060.00, 1160.00, 1260.00, 1360.00, 1460.00,
PV(1,2)= 0.001, 0.038, 0.465, 2.942, 12.112, 37.136, 92.165, 195.560, 368.240, 631.770, 1006.70,
RHOL(1,2)= .029981, .028801, .027550, .026229, .024837, .023375, .021842, .020238, .018564, .016819, .015003,
CP(1,2)= 0.41480, 0.46780, 0.52080, 0.57380, 0.62680, 0.67980, 0.73280, 0.78580, 0.83880, 0.89180, 0.94480,
LAM(1,2)= 148.120, 146.170, 140.810, 132.030, 119.830, 104.210, 85.164, 62.702, 36.820, 7.518,
TFILM(1,2)= 460.00, 660.00, 860.00, 1060.00, 1260.00, 1460.00, 1660.00, 1860.00, 2060.00, 2260.00, 2460.00,
VVIS(1,2)= 0.38400, 0.46400, 0.54400, 0.62400, 0.70400, 0.78400, 0.86400, 0.94400, 1.02400, 1.10400, 1.18400,
KVAP(1,2)= 0.092, 0.213, 0.333, 0.454, 0.574, 0.694, 0.814, 0.934, 1.054, 1.174, 1.294,
CPVAP(1,2)= 0.297, 0.420, 0.531, 0.630, 0.717, 0.792, 0.861, 0.924, 0.981, 1.038, 1.095,
$END

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METHANE.MID

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$INPUT
PCRT= 731, 667,
FLAMEF= 1,          TFLAME=6488,
NAMEG='LOX','METHANE',
NSP= 5,
SPNAME= '    CH4','    CO','    CO2','    H2','    H2O',
WM(1)=   16.04,    28.01,    44.01,    2.02,    18.02,
EPSI(1,1)= 148.600,  91.700,  195.200,  59.700,  809.100,
SIGMA(1,1)= 3.7580,  3.6900,  3.9410,  2.8270,  2.6410,
SIGOF=  3.4670,    3.4670,    WTMOL= 32.0000, 16.0400,
EPSOF= 106.700, 148.600,
NPRES= 3,
PRSS=  500.000, 1000.000, 1500.000,
NR= 7,
R(1)=           0.30, 0.60, 0.80, 1.00, 1.20, 1.50, 2.00,
YSP(1, 1,1)= 0.72, 0.37, 0.22, 0.12, 0.05, 0.00, 0.00,
YSP(1, 2,1)= 0.03, 0.16, 0.22, 0.26, 0.29, 0.31, 0.29,
YSP(1, 3,1)= 0.06, 0.05, 0.04, 0.03, 0.03, 0.03, 0.04,
YSP(1, 4,1)= 0.11, 0.33, 0.43, 0.50, 0.54, 0.52, 0.37,
YSP(1, 5,1)= 0.08, 0.09, 0.09, 0.09, 0.09, 0.14, 0.30,
YSP(1, 1,2)= 0.73, 0.40, 0.25, 0.13, 0.06, 0.00, 0.00,
YSP(1, 2,2)= 0.03, 0.15, 0.21, 0.26, 0.29, 0.31, 0.29,
YSP(1, 3,2)= 0.06, 0.05, 0.04, 0.03, 0.03, 0.03, 0.04,
YSP(1, 4,2)= 0.09, 0.30, 0.40, 0.48, 0.52, 0.52, 0.37,
YSP(1, 5,2)= 0.09, 0.10, 0.10, 0.10, 0.10, 0.14, 0.30,
YSP(1, 1,3)= 0.75, 0.40, 0.25, 0.13, 0.07, 0.00, 0.00,
YSP(1, 2,3)= 0.02, 0.15, 0.21, 0.25, 0.28, 0.31, 0.30,
YSP(1, 3,3)= 0.06, 0.05, 0.04, 0.03, 0.03, 0.03, 0.04,
YSP(1, 4,3)= 0.08, 0.29, 0.39, 0.46, 0.51, 0.52, 0.36,
YSP(1, 5,3)= 0.09, 0.11, 0.11, 0.11, 0.11, 0.14, 0.30,
WMTAB(1,1)= 16.8, 14.9, 14.0, 13.3, 12.8, 13.4, 16.0,
WMTAB(1,2)= 17.0, 15.2, 14.3, 13.6, 13.1, 13.4, 16.0,
WMTAB(1,3)= 17.1, 15.4, 14.4, 13.7, 13.3, 13.4, 16.0,
TCL(1,1)= 1603, 1946, 2079, 2197, 2336, 3000, 4588,
TCL(1,2)= 1639, 2023, 2171, 2300, 2444, 3008, 4598,
TCL(1,3)= 1659, 2069, 2227, 2364, 2512, 3020, 4603,
FGAMT(1)= 1.13, 1.15, 1.16, 1.18, 1.20, 1.28, 1.23,
NT= 6,
TTAB(1)= 540.00,1080.00,1980.00,3060.00,4860.00,7020.00,
VSP(1,1)= 0.6277, 1.0780, 1.6370, 2.1770, 2.9420, 3.7350,
VSP(1,2)= 0.9939, 1.6320, 2.4160, 3.2090, 4.3320, 5.4930,
VSP(1,3)= 0.8512, 1.5200, 2.3500, 3.1490, 4.2450, 5.4020,
VSP(1,4)= 0.4194, 0.6580, 0.9755, 1.2918, 1.7409, 2.2070,
VSP(1,5)= 0.4995, 0.7952, 1.1790, 1.5634, 2.1077, 2.6716,
VSP(1,6)= 0.6137, 1.2033, 2.2018, 3.2518, 4.6926, 6.1211,
VSP(1,7)= 1.0561, 1.7466, 2.6156, 3.4679, 4.6870, 5.9441,
VSP(1,8)= 1.1558, 1.9118, 2.8626, 3.7955, 5.1299, 6.5058,
VSP(1,9)= 1.1065, 1.7807, 2.6403, 3.5110, 4.7368, 6.0046,
CPTAB(1,1)= 8.535, 12.484, 18.052, 21.580, 23.895, 24.855,
CPTAB(1,2)= 6.965, 7.275, 8.056, 8.533, 8.837, 8.986,
CPTAB(1,3)= 8.863, 11.266, 13.201, 14.145, 14.732, 15.022,
CPTAB(1,4)= 4.968, 4.968, 4.968, 4.968, 4.968, 4.968,
CPTAB(1,5)= 6.995, 7.009, 7.307, 7.907, 8.637, 9.125,
CPTAB(1,6)= 8.028, 8.680, 10.163, 11.699, 13.122, 13.933,
CPTAB(1,7)= 5.234, 5.050, 4.994, 4.980, 4.990, 5.081,
CPTAB(1,8)= 7.023, 7.671, 8.438, 8.853, 9.388, 9.859,
CPTAB(1,9)= 6.965, 7.003, 7.422, 8.046, 8.666, 9.038,
NTL= 1, 8,          NTFLM= 1, 6,
TLI(1,2)= 164.00, 190.00, 215.00, 240.00, 265.00, 290.00, 315.00,
343.00,
PV(1,2)= 1.703, 8.495, 26.406, 64.195,131.769,239.900,400.575,
667.003,
RHOL(1,2)= .016314,.015591,.014859,.014056,.013150,.012082,.010686,
.005796,
CP(1,2)= 0.786, 0.820, 0.852, 0.890, 0.960, 1.079, 1.399,
6.085,
LAM(1,2)= 233.84, 224.64, 213.65, 199.80, 181.82, 157.69, 123.43,
1.00,
TFILM(1,2)= 180.00, 300, 500, 1000, 2500, 5000, 6400,
VVIS(1,2)= .0217, .3626, .5840, 1.011, 1.888, 2.960, 3.467,
KVAP(1,2)= 0.127, 0.231, 0.426, 1.036, 3.257, 6.377, 7.847,
CPVAP(1,2)= 0.405, 0.441, 0.514, 0.740, 1.272, 1.608, 1.687,
$END

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SINPUT
PCRT=1470, 1195,
NAMES='N2O4', 'MMH',
NPRES= 3,
NSP=12,
SPNAME= '      ' H', '      ' H2O', '      ' N2', '      ' CO', '      ' CO2',
          '      ' HO', '      ' O2', '      ' NO', '      ' O', '      ' CH4', '      ' H3N',
WM(1)= 1.00, 2.00, 18.00, 28.00, 28.00, 44.00, 17.00, 32.00, 30.00, 16.00, 16.00, 17.00,
EPSI(1,1)= 37.000, 59.700, 809.000, 71.400, 91.700, 195.000, 79.800, 106.700, 116.700, 106.700, 148.600, 558.000,
SIGMA(1,1)= 2.7100, 2.8300, 2.6400, 3.8000, 3.6900, 3.9400, 3.1500, 3.4700, 3.4900, 3.0500, 3.7600, 2.9000,
SIGOF= 3.9690, 4.2460, WTMOL= 46.0000, 42.0000,
PRSS= 50.000, 500.000, 3000.000, EPSOF= 331.900, 467.400,
NR= 10,
R(1)= 0.500, 1.000, 1.500, 2.000, 2.300, 2.800, 3.300, 4.000, 6.000, 10.000,
YSP(1, 1,1)= 0.0, 0.0040, 0.0270, 0.0320, 0.0270, 0.0180, 0.0117, 0.0061, 0.0007, 0.0000,
YSP(1, 2,1)= 0.5630, 0.3740, 0.1960, 0.0950, 0.0640, 0.0370, 0.0223, 0.0117, 0.0019, 0.0000,
YSP(1, 3,1)= 0.0040, 0.1680, 0.2940, 0.3400, 0.3430, 0.3350, 0.3205, 0.2991, 0.2447, 0.3350,
YSP(1, 4,1)= 0.2400, 0.2720, 0.2970, 0.3100, 0.3140, 0.3190, 0.3223, 0.3263, 0.3339, 0.3393,
YSP(1, 5,1)= 0.1870, 0.1680, 0.1400, 0.1050, 0.0860, 0.0610, 0.0420, 0.0242, 0.0039, 0.0000,
YSP(1, 6,1)= 0.0010, 0.0130, 0.0300, 0.0520, 0.0630, 0.0760, 0.0836, 0.0884, 0.0820, 0.0570,
YSP(1, 7,1)= 0.0, 0.0, 0.0130, 0.0400, 0.0500, 0.0570, 0.0559, 0.0478, 0.0212, 0.0019,
YSP(1, 8,1)= 0.0, 0.0, 0.0010, 0.0120, 0.0280, 0.0630, 0.1024, 0.1576, 0.2864, 0.4247,
YSP(1, 9,1)= 0.0, 0.0001, 0.0001, 0.0060, 0.0120, 0.0170, 0.0215, 0.0235, 0.0199, 0.0067,
YSP(1,10,1)= 0.0, 0.0, 0.0010, 0.0080, 0.0130, 0.0170, 0.0178, 0.0153, 0.0053, 0.0002,
YSP(1,11,1)= 0.0050,
YSP(1, 1,2)= 0.0, 0.0010, 0.0130, 0.0180, 0.0150, 0.0100, 0.0056, 0.0025, 0.0002, 0.0000,
YSP(1, 2,2)= 0.5370, 0.3750, 0.2000, 0.0880, 0.0550, 0.0280, 0.0152, 0.0070, 0.0008, 0.0000,
YSP(1, 3,2)= 0.0180, 0.1690, 0.3060, 0.3670, 0.3720, 0.3600, 0.3412, 0.3146, 0.2507, 0.1706,
YSP(1, 4,2)= 0.2470, 0.2730, 0.3010, 0.3160, 0.3200, 0.3240, 0.3261, 0.3287, 0.3346, 0.3393,
YSP(1, 5,2)= 0.1760, 0.1680, 0.1420, 0.1040, 0.0810, 0.0520, 0.0323, 0.0160, 0.0017, 0.0000,
YSP(1, 6,2)= 0.0030, 0.0130, 0.0300, 0.0560, 0.0710, 0.0870, 0.0957, 0.0983, 0.0846, 0.0570,
YSP(1, 7,2)= 0.0, 0.0, 0.0070, 0.0320, 0.0440, 0.0510, 0.0493, 0.0398, 0.0146, 0.0011,
YSP(1, 8,2)= 0.0, 0.0, 0.0, 0.0070, 0.0200, 0.0550, 0.0968, 0.1553, 0.2882, 0.4250,
YSP(1, 9,2)= 0.0, 0.0, 0.0010, 0.0080, 0.0140, 0.0220, 0.0267, 0.0288, 0.0221, 0.0067,
YSP(1,10,2)= 0.0, 0.0, 0.0, 0.0040, 0.0070, 0.0110, 0.0108, 0.0086, 0.0022, 0.0001,
YSP(1,11,2)= 0.0200,
YSP(1,12,2)= 0.0010,
YSP(1, 1,3)= 0.0, 0.0010, 0.0070, 0.0110, 0.0090, 0.0050, 0.0028, 0.0011, 0.0001, 0.0000,
YSP(1, 2,3)= 0.5380, 0.3760, 0.2010, 0.0820, 0.0460, 0.0210, 0.0101, 0.0041, 0.0004, 0.0000,
YSP(1, 3,3)= 0.0380, 0.1690, 0.3120, 0.3880, 0.3950, 0.3800, 0.3565, 0.3253, 0.2540, 0.1708,
YSP(1, 4,3)= 0.2580, 0.2730, 0.3030, 0.3210, 0.3260, 0.3280, 0.3288, 0.3302, 0.3348, 0.3393,
YSP(1, 5,3)= 0.1600, 0.1680, 0.1430, 0.1020, 0.0750, 0.0430, 0.0236, 0.0101, 0.0008, 0.0000,
YSP(1, 6,3)= 0.0040, 0.0130, 0.0300, 0.0610, 0.0800, 0.1000, 0.1061, 0.1053, 0.0857, 0.0571,
YSP(1, 7,3)= 0.0, 0.0, 0.0040, 0.0240, 0.0360, 0.0440, 0.0418, 0.0319, 0.0102, 0.0007,
YSP(1, 8,3)= 0.0, 0.0, 0.0, 0.0040, 0.0140, 0.0490, 0.0925, 0.1540, 0.2891, 0.4250,
YSP(1, 9,3)= 0.0, 0.0, 0.0, 0.0050, 0.0150, 0.0230, 0.0304, 0.0324, 0.0232, 0.0068,
YSP(1,10,3)= 0.0, 0.0, 0.0, 0.0020, 0.0040, 0.0070, 0.0067, 0.0049, 0.0010, 0.0000,
YSP(1,12,3)= 0.0020,
WMTAB(1,1)= 13.2800, 16.7200, 19.5800, 21.6600, 22.6100, 23.8800, 24.8740, 25.9350, 27.6950, 28.9070,
WMTAB(1,2)= 13.6900, 16.7400, 19.8100, 22.1100, 23.1200, 24.4000, 25.3550, 26.3280, 27.8420, 28.9160,
WMTAB(1,3)= 14.3000, 16.7500, 19.9200, 22.4300, 23.5200, 24.8000, 25.7020, 26.5820, 27.9140, 28.9220,
TC1(1,1)= 2386.00, 4224.00, 5215.00, 5513.00, 5529.00, 5463.00, 5351.00, 5168.00, 4587.00, 3515.00,
TC1(1,2)= 2569.00, 4255.00, 5456.00, 5940.00, 5983.00, 5893.00, 5729.00, 5467.00, 4700.00, 3522.00,
TC1(1,3)= 2819.00, 4265.00, 5572.00, 6239.00, 6325.00, 6211.00, 5996.00, 5657.00, 4754.00, 3525.00,
FGAMT(1)= 1.258, 1.258, 1.188, 1.144, 1.136, 1.135, 1.138, 1.146, 1.181, 1.239,
NT= 6,
TTAB(1)= 540.00, 1080.00, 1980.00, 3060.00, 4860.00, 7020.00,
VSP(1,1)= 0.4190, 0.6580, 0.9760, 1.2920, 1.7140, 2.2070,
VSP(1,2)= 0.5000, 0.7950, 1.1790, 1.5640, 2.1080, 2.6720,
VSP(1,3)= 0.6140, 1.2030, 2.2020, 3.2520, 4.6930, 6.1210,
VSP(1,4)= 0.9950, 1.5980, 2.3670, 3.1460, 4.2420, 5.3780,
VSP(1,5)= 0.9940, 1.6230, 2.4160, 3.2090, 4.3320, 5.4930,
VSP(1,6)= 0.8510, 1.5200, 2.3500, 3.1490, 4.2450, 5.4020,
VSP(1,7)= 1.1020, 1.7810, 2.6400, 3.5110, 4.7370, 6.0040,
VSP(1,8)= 1.1560, 1.9120, 2.8630, 3.7960, 5.1300, 6.5060,
VSP(1,9)= 1.0750, 1.7950, 2.6970, 3.5710, 4.8330, 6.1300,
VSP(1,10)= 1.0560, 1.7470, 2.6160, 3.4680, 4.6870, 5.9440,
VSP(1,11)= 0.6280, 1.0780, 1.6370, 2.1770, 2.9420, 3.7350,
VSP(1,12)= 0.5830, 1.1730, 2.0620, 2.9320, 4.1090, 5.2830,
CPTAB(1,1)= 2.500, 2.500, 2.500, 2.500, 2.500, 2.500,
CPTAB(1,2)= 7.000, 7.050, 7.350, 7.990, 8.620, 9.110,
CPTAB(1,3)= 8.080, 8.730, 10.220, 11.750, 13.200, 14.010,
CPTAB(1,4)= 7.000, 7.240, 8.000, 8.510, 8.850, 8.990,
CPTAB(1,5)= 7.000, 7.300, 8.100, 8.600, 8.910, 9.050,
CPTAB(1,6)= 8.940, 11.350, 13.290, 14.340, 14.830, 15.130,
CPTAB(1,7)= 7.000, 7.040, 7.460, 8.090, 8.730, 9.100,
CPTAB(1,8)= 7.070, 7.700, 8.470, 8.890, 9.440, 9.920,
CPTAB(1,9)= 7.170, 7.500, 8.280, 8.690, 8.970, 9.120,
CPTAB(1,10)= 5.260, 5.090, 5.020, 5.010, 5.020, 5.120,
CPTAB(1,11)= 8.570, 12.560, 18.150, 21.700, 24.000, 25.000,
CPTAB(1,12)= 8.550, 10.720, 14.000, 16.530, 18.430, 19.350,
NTL= 10, 12, NTFILM= 7, 6,
TLI(1,1)= 400.00, 440.00, 480.00, 520.00, 560.00, 600.00, 640.00, 680.00, 720.00, 760.00,
TLI(1,2)= 500.00, 550.00, 600.00, 650.00, 700.00, 750.00, 800.00, 850.00, 900.00, 950.00, 1000.00, 1050.00,
PV(1,1)= 0.270, 0.850, 3.940, 11.800, 30.000, 80.000, 180.000, 330.000, 660.000, 1200.00,
PV(1,2)= 0.280, 1.420, 4.930, 13.300, 29.700, 57.900, 101.500, 164.000, 248.000, 357.000, 491.000, 651.000,
RHOL(1,1)= .058000, .055600, .054100, .052700, .050850, .048700, .046300, .043500, .039150, .032400,
RHOL(1,2)= .032100, .031100, .030300, .029200, .028200, .027400, .026400, .024900, .023500, .021700, .019500, .016200,
CP(1,1)= 0.35000, 0.35000, 0.35300, 0.37200, 0.38800, 0.41400, 0.46400, 0.54300, 0.70000, 0.87000,
CP(1,2)= 0.69500, 0.70100, 0.70700, 0.71300, 0.72100, 0.73100, 0.74000, 0.75000, 0.76100, 0.77500, 0.79000, 0.80500,
LAM(1,1)= 435.000, 430.000, 422.000, 412.000, 403.000, 392.000, 379.000, 365.000, 346.000, 315.000,
LAM(1,2)= 402.000, 368.000, 343.000, 324.000, 309.000, 296.000, 286.000, 275.000, 260.000, 235.000, 210.000, 170.000,
TFILM(1,1)= 400.00, 600.00, 1000.00, 1600.00, 2400.00, 3200.00, 4000.00,
TFILM(1,2)= 400.00, 800.00, 1200.00, 2000.00, 2800.00, 4000.00,
VVIS(1,1)= 0.62400, 0.92000, 1.57000, 2.34000, 3.21000, 3.91000, 4.57000,
VVIS(1,2)= 0.33400, 0.58400, 0.84400, 1.33000, 1.75000, 2.25000,
KVAP(1,1)= 0.094, 0.224, 0.485, 0.875, 1.390, 1.910, 2.440,
KVAP(1,2)= 0.100, 0.310, 0.584, 1.180, 1.620, 2.050,
CFVAP(1,1)= 0.231, 0.238, 0.253, 0.269, 0.286, 0.297, 0.300,
CFVAP(1,2)= 0.450, 0.560, 0.655, 0.798, 0.853, 0.876,
SEND
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N2H4.DAT

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$INPUT
PCRT=1470, 2131,
NAMES='NTO', 'N2H4',
NPRES= 3,
NSP= 9,
SPNAME= ' H', ' H2', ' H2O', ' N2', ' HO',
        ' O2', ' H3N', ' NO', ' O',
WM(1)= 1.00, 2.00, 18.00, 28.00, 17.00,
        32.00, 17.00, 30.00, 16.00,
EPSI(1,1)= 37.000, 59.700, 809.000, 71.400, 79.800,
        106.700, 558.000, 116.700, 106.700,
SIGMA(1,1)= 2.7100, 2.8300, 2.6400, 3.8000, 3.1500,
        3.4700, 2.9000, 3.4900, 3.0500,
SIGOF= 3.9690, 4.0290, WTMOL= 46.0000, 32.0000,
PRSS= 100.000, 300.000, 1000.000, EPSOF= 331.900, 502.800,
NR= 9,
R(1)= 15.000, 10.000, 5.000, 2.000, 1.000,
        0.500, 0.200, 0.100, 0.066,
YSP(1, 1,1)= 0.0, 0.0, 0.0, 0.0070, 0.0200,
        0.0010,
YSP(1, 2,1)= 0.0, 0.0, 0.0, 0.0200, 0.1800,
        0.4080, 0.5600, 0.6120, 0.6310,
YSP(1, 3,1)= 0.1130, 0.1610, 0.2740, 0.4250, 0.3880,
        0.2190, 0.0900, 0.0460, 0.0300,
YSP(1, 4,1)= 0.3510, 0.3600, 0.3750, 0.3910, 0.3920,
        0.3690, 0.3480, 0.3400, 0.3390,
YSP(1, 5,1)= 0.0, 0.0, 0.0, 0.0050, 0.0450, 0.0130,
YSP(1, 6,1)= 0.5330, 0.4790, 0.3380, 0.0790, 0.0020,
YSP(1, 8,1)= 0.0, 0.0, 0.0, 0.0110, 0.0200,
YSP(1, 9,1)= 0.0, 0.0, 0.0, 0.0900,
YSP(1, 1,2)= 0.0, 0.0, 0.0, 0.0040, 0.0150,
YSP(1, 2,2)= 0.0, 0.0, 0.0, 0.0160, 0.1790,
        0.4100, 0.5600, 0.6120, 0.6280,
YSP(1, 3,2)= 0.1130, 0.1610, 0.2740, 0.4370, 0.3960,
        0.2190, 0.0900, 0.0450, 0.0300,
YSP(1, 4,2)= 0.3510, 0.3600, 0.3720, 0.3930, 0.3960,
        0.3960, 0.3480, 0.3410, 0.3370,
YSP(1, 5,2)= 0.0, 0.0, 0.0020, 0.0410, 0.0110,
YSP(1, 6,2)= 0.5330, 0.4790, 0.3380, 0.0780,
YSP(1, 7,2)= 0.0, 0.0, 0.0, 0.0, 0.0,
        0.0, 0.0, 0.0, 0.0020,
YSP(1, 8,2)= 0.0, 0.0, 0.0100, 0.0200,
YSP(1, 9,2)= 0.0, 0.0, 0.0, 0.0070,
YSP(1, 1,3)= 0.0, 0.0, 0.0, 0.0020, 0.0090,
YSP(1, 2,3)= 0.0, 0.0, 0.0, 0.0120, 0.1800,
        0.4110, 0.5590, 0.6090, 0.6260,
YSP(1, 3,3)= 0.1130, 0.1600, 0.2780, 0.4470, 0.4020,
        0.2200, 0.0900, 0.0450, 0.0300,
YSP(1, 4,3)= 0.3510, 0.3600, 0.3730, 0.3940, 0.3980,
        0.3700, 0.3470, 0.3400, 0.3370,
YSP(1, 5,3)= 0.0, 0.0, 0.0, 0.0370, 0.0070,
YSP(1, 6,3)= 0.5360, 0.4770, 0.3380, 0.0760,
YSP(1, 7,3)= 0.0, 0.0, 0.0, 0.0, 0.0,
        0.0, 0.0, 0.0030, 0.0050,
YSP(1, 8,3)= 0.0, 0.0, 0.0100, 0.0230,
YSP(1, 9,3)= 0.0, 0.0, 0.0, 0.0040,
WMTAB(1,1)= 29.0100,28.3200,26.5800,22.7400,18.7500,
        15.1300,12.5300,11.6200,11.3200,
WMTAB(1,2)= 29.0200,28.3200,26.5900,22.9000,18.8600,
        15.1400,12.5300,11.6300,11.3300,
WMTAB(1,3)= 29.0100,28.3200,26.6000,23.0500,18.9600,
        15.1400,12.5400,11.6600,11.3800,
TC1(1,1)= 1903.00,2533.00,3856.00,5290.00,5278.00,
        4018.00,2693.00,2156.00,1964.00,
TC1(1,2)= 1903.00,2533.00,3865.00,5429.00,5398.00,
        4025.00,2695.00,2158.00,1969.00,
TC1(1,3)= 1903.00,2532.00,3872.00,5558.00,5504.00,
        4014.00,2696.00,2165.00,1984.00,
FGANT(1)= 1.310, 1.287, 1.253, 1.225, 1.232,
        1.268, 1.318, 1.344, 1.353,
NT= 6,
TTAB(1)= 540.00,1080.00,1980.00,3060.00,4860.00,7020.00,
VSP(1,1)= 0.4190, 0.6580, 0.9760, 1.2920, 1.7410, 2.2070,
VSP(1,2)= 0.5000, 0.7920, 1.1790, 1.5640, 2.1080, 2.6720,
VSP(1,3)= 0.6140, 1.2030, 2.2020, 3.2520, 4.6930, 6.1210,
VSP(1,4)= 0.9950, 1.5980, 2.3670, 3.1460, 4.2420, 5.3780,
VSP(1,5)= 1.1020, 1.7810, 2.6400, 3.5110, 4.7370, 6.0040,
VSP(1,6)= 1.1560, 1.9120, 2.8630, 3.7960, 5.1300, 6.5060,
VSP(1,7)= 0.5830, 1.1730, 2.0620, 2.9320, 4.1090, 5.2830,
VSP(1,8)= 1.0750, 1.7950, 2.6970, 3.5710, 4.8330, 6.1300,
VSP(1,9)= 1.0560, 1.7470, 2.6160, 3.4680, 4.6870, 5.9440,
CPTAB(1,1)= 2.500, 2.500, 2.500, 2.500, 2.500, 2.500,
CPTAB(1,2)= 7.000, 7.050, 7.350, 7.990, 8.620, 9.110,
CPTAB(1,3)= 8.080, 8.730, 10.220, 11.750, 13.200, 14.010,
CPTAB(1,4)= 7.000, 7.240, 8.000, 8.510, 8.850, 8.990,
CPTAB(1,5)= 7.000, 7.040, 7.460, 8.090, 8.730, 9.100,
CPTAB(1,6)= 7.070, 7.700, 8.470, 8.890, 9.440, 9.920,
CPTAB(1,7)= 8.550, 10.720, 14.000, 16.530, 18.430, 19.350,
CPTAB(1,8)= 7.170, 7.500, 8.280, 8.690, 8.970, 9.120,
CPTAB(1,9)= 5.260, 5.090, 5.020, 5.010, 5.020, 5.120,
NTL= 10, 13, NTFILM= 7, 6,
TLI(1,1)= 400.00, 440.00, 480.00, 520.00, 560.00, 600.00,
        640.00, 680.00, 720.00, 760.00,
TLI(1,2)= 400.00, 500.00, 550.00, 600.00, 650.00, 700.00,
        750.00, 800.00, 850.00, 900.00, 950.00,1000.00,1050.00,
PV(1,1)= 0.270, 0.850, 3.940, 11.800, 30.000, 80.000,
        180.000,330.000,660.000,1200.00,
PV(1,2)= 0.001, 0.080, 0.480, 1.900, 6.000, 15.500,
        37.000, 75.000,160.000,250.000,430.000,660.000,960.000,
RHOL(1,1)= .058000,.055600,.054100,.052700,.050850,.048700,
        .046300,.043500,.039350,.032400,

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N2H4.DAT

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RHOL(1,2)= .038000,.036600,.035700,.034800,.033800,.032800,
            .031700,.030500,.029200,.028100,.027000,.026000,.025000,
CP(1,1)= 0.35000,0.35000,0.35300,0.37200,0.38800,0.41400,
          0.46400,0.54300,0.70000,0.87000,
CP(1,2)= .7014, .7295, .7435, .7575, .7716, .7856,
          .7997, .8137, .8277, .8418, .8558, .8698, .8839,
LAM(1,1)= 435.000,430.000,422.000,412.000,403.000,392.000,
          379.000,365.000,346.000,315.000,
LAM(1,2)= 606.52, 581.53, 569.95, 558.97, 548.60, 538.85,
          529.69, 521.14, 513.20, 505.86, 499.13, 493.02, 487.50,
TFILM(1,1)= 400.00, 600.00,1000.00,1600.00,2400.00,3200.00,4000.00,
TFILM(1,2)= 400.00, 800.00,1200.00,2000.00,2800.00,4000.00,
VVIS(1,1)= 0.62400,0.92000,1.57000,2.34000,3.21000,3.91000,4.57000,
VVIS(1,2)= .4252, .8085, 1.1917, 1.9582, 2.7247, 3.8745,
KVAP(1,1)= 0.094, 0.224, 0.485, 0.875, 1.390, 1.910, 2.440,
KVAP(1,2)= 0.140, 0.300, 0.450, 0.950, 1.500, 2.400,
CPVAP(1,1)= 0.231, 0.238, 0.253, 0.269, 0.286, 0.297, 0.300,
CPVAP(1,2)= 0.320, 0.500, 0.610, 0.740, 0.820, 0.900,
$END

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O2H2.DAT

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$INPUT
PCRT=731, 188,
FLAMEF= 1,
TFLAME=6250.,
NAMES='LOX','GH2',
NSP= 6,
SPNAME= ' H',' H2',' H2O',' O',' OH',' O2',
WM(1)= 1.01, 2.02, 18.02, 16.00, 17.01, 32.00,
EPSI(1,1)= 37.00, 59.7, 809.10, 106.70, 79.80, 106.70,
SIGMA(1,1)= 2.7080, 2.8270, 2.6410, 3.0500, 3.1470, 3.4670,
SIGOF= 3.4670, 2.8720, WTMOL= 32.0000, 2.02,
EPSOF= 106.700, 59.700,
NR = 12,
R = 0.100E+00, 0.300E+01, 0.400E+01, 0.450E+01, 0.500E+01, 0.550E+01,
0.600E+01, 0.650E+01, 0.700E+01, 0.750E+01, 0.800E+01, 0.100E+02,
NPRES= 3,
PRSS = 0.200E+03, 0.300E+03, 0.400E+03,
TC1(1,1)= 0.720E+03, 0.472E+04, 0.541E+04, 0.565E+04, 0.582E+04, 0.595E+04,
0.604E+04, 0.610E+04, 0.613E+04, 0.614E+04, 0.614E+04, 0.605E+04,
TC1(1,2)= 0.720E+03, 0.473E+04, 0.546E+04, 0.571E+04, 0.590E+04, 0.604E+04,
0.614E+04, 0.620E+04, 0.624E+04, 0.625E+04, 0.625E+04, 0.615E+04,
TC1(1,3)= 0.720E+03, 0.474E+04, 0.549E+04, 0.575E+04, 0.595E+04, 0.610E+04,
0.620E+04, 0.627E+04, 0.631E+04, 0.632E+04, 0.632E+04, 0.622E+04,
FGAMT(1)= 0.140E+01, 0.121E+01, 0.117E+01, 0.115E+01, 0.114E+01, 0.114E+01,
0.113E+01, 0.113E+01, 0.113E+01, 0.113E+01, 0.113E+01, 0.113E+01,
WMTAB(1,1)= 0.222E+01, 0.222E+01, 0.222E+01, 0.802E+01, 0.803E+01, 0.803E+01,
0.987E+01, 0.989E+01, 0.991E+01, 0.107E+02, 0.108E+02, 0.108E+02,
WMTAB(1,2)= 0.115E+02, 0.116E+02, 0.116E+02, 0.123E+02, 0.124E+02, 0.124E+02,
0.131E+02, 0.131E+02, 0.132E+02, 0.137E+02, 0.138E+02, 0.139E+02,
WMTAB(1,3)= 0.144E+02, 0.145E+02, 0.145E+02, 0.150E+02, 0.151E+02, 0.151E+02,
0.156E+02, 0.157E+02, 0.157E+02, 0.176E+02, 0.177E+02, 0.177E+02,
YSP(1, 1, 1)= 0.000E+00, 0.866E-02, 0.301E-01, 0.410E-01, 0.496E-01, 0.550E-01,
0.572E-01, 0.568E-01, 0.546E-01, 0.512E-01, 0.472E-01, 0.314E-01,
YSP(1, 2, 1)= 0.987E+00, 0.615E+00, 0.477E+00, 0.411E+00, 0.351E+00, 0.297E+00,
0.251E+00, 0.213E+00, 0.180E+00, 0.153E+00, 0.131E+00, 0.737E-01,
YSP(1, 3, 1)= 0.126E-01, 0.375E+00, 0.482E+00, 0.526E+00, 0.563E+00, 0.592E+00,
0.614E+00, 0.630E+00, 0.641E+00, 0.647E+00, 0.650E+00, 0.642E+00,
YSP(1, 4, 1)= 0.000E+00, 0.120E-04, 0.399E-03, 0.118E-02, 0.268E-02, 0.502E-02,
0.810E-02, 0.117E-01, 0.154E-01, 0.189E-01, 0.221E-01, 0.298E-01,
YSP(1, 5, 1)= 0.000E+00, 0.131E-02, 0.104E-01, 0.199E-01, 0.322E-01, 0.463E-01,
0.610E-01, 0.750E-01, 0.873E-01, 0.976E-01, 0.106E+00, 0.120E+00,
YSP(1, 6, 1)= 0.000E+00, 0.298E-05, 0.161E-03, 0.602E-03, 0.171E-02, 0.395E-02,
0.780E-02, 0.136E-01, 0.215E-01, 0.314E-01, 0.432E-01, 0.102E+00,
YSP(1, 1, 2)= 0.000E+00, 0.750E-02, 0.266E-01, 0.369E-01, 0.452E-01, 0.506E-01,
0.530E-01, 0.528E-01, 0.507E-01, 0.475E-01, 0.437E-01, 0.286E-01,
YSP(1, 2, 2)= 0.987E+00, 0.616E+00, 0.479E+00, 0.413E+00, 0.352E+00, 0.298E+00,
0.251E+00, 0.212E+00, 0.178E+00, 0.151E+00, 0.128E+00, 0.706E-01,
YSP(1, 3, 2)= 0.126E-01, 0.375E+00, 0.485E+00, 0.530E+00, 0.568E+00, 0.599E+00,
0.622E+00, 0.639E+00, 0.650E+00, 0.657E+00, 0.660E+00, 0.651E+00,
YSP(1, 4, 2)= 0.000E+00, 0.860E-05, 0.316E-03, 0.973E-03, 0.228E-02, 0.439E-02,
0.724E-02, 0.106E-01, 0.142E-01, 0.176E-01, 0.207E-01, 0.280E-01,
YSP(1, 5, 2)= 0.000E+00, 0.112E-02, 0.943E-02, 0.183E-01, 0.303E-01, 0.443E-01,
0.591E-01, 0.733E-01, 0.860E-01, 0.966E-01, 0.105E+00, 0.119E+00,
YSP(1, 6, 2)= 0.000E+00, 0.214E-05, 0.128E-03, 0.496E-03, 0.146E-02, 0.347E-02,
0.705E-02, 0.126E-01, 0.203E-01, 0.300E-01, 0.418E-01, 0.102E+00,
YSP(1, 1, 3)= 0.000E+00, 0.664E-02, 0.243E-01, 0.341E-01, 0.422E-01, 0.476E-01,
0.501E-01, 0.500E-01, 0.481E-01, 0.450E-01, 0.413E-01, 0.266E-01,
YSP(1, 2, 3)= 0.987E+00, 0.617E+00, 0.480E+00, 0.415E+00, 0.354E+00, 0.299E+00,
0.251E+00, 0.211E+00, 0.177E+00, 0.149E+00, 0.126E+00, 0.683E-01,
YSP(1, 3, 3)= 0.126E-01, 0.376E+00, 0.486E+00, 0.533E+00, 0.572E+00, 0.604E+00,
0.628E+00, 0.645E+00, 0.657E+00, 0.664E+00, 0.668E+00, 0.658E+00,
YSP(1, 4, 3)= 0.000E+00, 0.677E-05, 0.266E-03, 0.841E-03, 0.202E-02, 0.397E-02,
0.665E-02, 0.987E-02, 0.133E-01, 0.166E-01, 0.197E-01, 0.268E-01,
YSP(1, 5, 3)= 0.000E+00, 0.994E-03, 0.872E-02, 0.172E-01, 0.289E-01, 0.428E-01,
0.576E-01, 0.720E-01, 0.849E-01, 0.958E-01, 0.104E+00, 0.119E+00,
YSP(1, 6, 3)= 0.000E+00, 0.168E-05, 0.107E-03, 0.428E-03, 0.129E-02, 0.315E-02,
0.653E-02, 0.119E-01, 0.194E-01, 0.291E-01, 0.408E-01, 0.101E+00,
NT = 6,
TTAB(1)= 540.00, 1080.00, 1980.00, 3060.00, 4860.00, 7020.00,
VSP(1,1)= 0.4194, 0.6580, 0.9755, 1.2918, 1.7409, 2.2070,
VSP(1,2)= 0.4995, 0.7952, 1.1790, 1.5634, 2.1077, 2.6716,
VSP(1,3)= 0.6137, 1.2033, 2.2018, 3.2518, 4.6926, 6.1211,
VSP(1,4)= 1.0561, 1.7466, 2.6156, 3.4679, 4.6870, 5.9441,
VSP(1,5)= 1.1065, 1.7807, 2.6403, 3.5110, 4.7368, 6.0046,
VSP(1,6)= 1.1558, 1.9118, 2.8626, 3.7955, 5.1299, 6.5058,
CPTAB(1,1)= 4.968, 4.968, 4.968, 4.968, 4.968, 4.968,
CPTAB(1,2)= 6.995, 7.009, 7.307, 7.907, 8.637, 9.125,
CPTAB(1,3)= 8.028, 8.680, 10.163, 11.699, 13.122, 13.933,
CPTAB(1,4)= 5.234, 5.050, 4.994, 4.980, 4.990, 5.081,
CPTAB(1,5)= 6.965, 7.003, 7.422, 8.046, 8.666, 9.038,
CPTAB(1,6)= 7.023, 7.671, 8.438, 8.853, 9.388, 9.859,
NTL= 0, 0, NTFLM= 7, 0,
TFILM(1,1)= 180.00, 540.00, 1080.00, 1800.00, 2700.00, 3600.00, 5400.00,
VVIS(1,1)= 0.45940, 1.23790, 2.04750, 2.88240, 3.74240, 4.52090, 5.88170,
KVAP(1,1)= 0.145, 0.393, 0.705, 1.125, 1.453, 1.809, 2.476,
CPVAP(1,1)= 0.217, 0.220, 0.240, 0.261, 0.273, 0.282, 0.298,
$END

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LOXH2. MID

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$INPUT
PCRT=731, 188,
FLAMEF= 1,
TFLAME=6250.,
NAMES='LOX','LH2',
NSP= 6,
SPNAME= ' H',' H2',' H2O',' O',' OH',' O2',
WM(1)= 1.01, 2.02, 18.02, 16.00, 17.01, 32.00,
EPSI(1,1)= 37.00, 59.7, 809.10, 106.70, 79.80, 106.70,
SIGMA(1,1)= 2.7080, 2.8270, 2.6410, 3.0500, 3.1470, 3.4670,
SIGOF= 3.4670, 2.8720, WTMOL= 32.0000, 2.02,
EPSOF= 106.700, 59.700,
NR = 10,
R = 1., 2., 3., 4., 5., 6., 7., 8., 10., 20.,
NPRES= 3,
PRSS = 400., 1000., 1500.,
TC1(1, 1)= 1759., 3236., 4409., 5259., 5800.,
6100., 6229., 6249., 6143., 5236.,
WMTAB(1, 1)= 4.032, 6.048, 8.050, 9.969, 11.731,
13.308, 14.692, 15.898, 17.890, 23.533,
YSP(1, 1, 1)= .000000, .000058, .003002, .016374, .033894,
.043313, .042540, .036462, .022978, .001617,
YSP(1, 2, 1)= .873999, .747948, .619632, .485212, .355940,
.248985, .171511, .119597, .062565, .005154,
YSP(1, 3, 1)= .126001, .251993, .377000, .492939, .585778,
.647333, .679100, .689275, .676461, .523664,
YSP(1, 4, 1)= .000000, .000000, .000001, .000109, .001255,
.005071, .011212, .017289, .023908, .009966,
YSP(1, 5, 1)= .000000, .000001, .000365, .005320, .022304,
.050062, .078084, .098047, .112018, .051988,
YSP(1, 6, 1)= .000000, .000000, .000000, .000045, .000818,
.005188, .017423, .039091, .101626, .407108,
TC1(1, 2)= 1759., 3236., 4420., 5321., 5931.,
6291., 6452., 6479., 6350., 5317.,
WMTAB(1, 2)= 4.032, 6.048, 8.055, 10.001, 11.813,
13.446, 14.875, 16.104, 18.097, 23.626,
FGAMT(1)= 1.3586, 1.2837, 1.2337, 1.1897, 1.1588,
1.1406, 1.1325, 1.1305, 1.1321, 1.1580,
YSP(1, 1, 2)= .000000, .000037, .001957, .011590, .026046,
.035074, .034997, .029632, .017756, .001023,
YSP(1, 2, 2)= .873999, .747966, .620455, .488366, .359178,
.248424, .166297, .111832, .054968, .003855,
YSP(1, 3, 2)= .126001, .251996, .377347, .496094, .595383,
.664662, .701741, .713414, .697604, .530255,
YSP(1, 4, 2)= .000000, .000000, .000000, .000056, .000771,
.003617, .008851, .014362, .020186, .007442,
YSP(1, 5, 2)= .000000, .000001, .000240, .003871, .018107,
.044372, .073341, .094622, .108512, .046172,
YSP(1, 6, 2)= .000000, .000000, .000000, .000023, .000505,
.003793, .014598, .035792, .100314, .410551,
TC1(1, 3)= 1759., 3236., 4424., 5343., 5983.,
6372., 6551., 6581., 6440., 5349.,
WMTAB(1, 3)= 4.032, 6.048, 8.056, 10.013, 11.846,
13.506, 14.956, 16.196, 18.188, 23.664,
YSP(1, 1, 3)= .000000, .000030, .001614, .009852, .022929,
.031661, .031861, .026813, .015668, .000825,
YSP(1, 2, 3)= .873999, .747972, .620726, .489511, .360462,
.248102, .163759, .108079, .051492, .003362,
YSP(1, 3, 3)= .126001, .251997, .377462, .497256, .599309,
.672288, .712143, .724610, .707180, .532970,
YSP(1, 4, 3)= .000000, .000000, .000000, .000041, .000607,
.003054, .007870, .013118, .018590, .006486,
YSP(1, 5, 3)= .000000, .000001, .000198, .003324, .016285,
.041593, .070814, .092679, .106480, .043571,
YSP(1, 6, 3)= .000000, .000000, .000000, .000017, .000398,
.003239, .013353, .034298, .099805, .411976,
NT = 6,
TTAB(1)= 540.00,1080.00,1980.00,3060.00,4860.00,7020.00,
VSP(1,1)= 0.4194, 0.6580, 0.9755, 1.2918, 1.7409, 2.2070,
VSP(1,2)= 0.4995, 0.7952, 1.1790, 1.5634, 2.1077, 2.6716,
VSP(1,3)= 0.6137, 1.2033, 2.2018, 3.2518, 4.6926, 6.1211,
VSP(1,4)= 1.0561, 1.7466, 2.6156, 3.4679, 4.6870, 5.9441,
VSP(1,5)= 1.1065, 1.7807, 2.6403, 3.5110, 4.7368, 6.0046,
VSP(1,6)= 1.1558, 1.9118, 2.8626, 3.7955, 5.1299, 6.5058,
CPTAB(1,1)= 4.968, 4.968, 4.968, 4.968, 4.968, 4.968,
CPTAB(1,2)= 6.995, 7.009, 7.307, 7.907, 8.637, 9.125,
CPTAB(1,3)= 8.028, 8.680, 10.163, 11.699, 13.122, 13.933,
CPTAB(1,4)= 5.234, 5.050, 4.994, 4.980, 4.990, 5.081,
CPTAB(1,5)= 6.965, 7.003, 7.422, 8.046, 8.666, 9.038,
CPTAB(1,6)= 7.023, 7.671, 8.438, 8.853, 9.388, 9.859,
NTL= 0, 0, NTFILM= 7, 0,
TFILM(1,1)= 180.00, 540.00,1080.00,1800.00,2700.00,3600.00,5400.00,
VVIS(1,1)= 0.45940,1.23790,2.04750,2.88240,3.74240,4.52090,5.88170,
KVAP(1,1)= 0.145, 0.393, 0.705, 1.125, 1.453, 1.809, 2.476,
CPVAP(1,1)= 0.217, 0.220, 0.240, 0.261, 0.273, 0.282, 0.298,
$END

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LOXH2.DAT

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$INPUT
PCRTIT=731, 188,
FLAMEF= 1,
TFLAME=6250.,
NAMES='LOX','LH2',
NSP= 6,
SPNAME= ' H',' H2',' H2O',' O',' OH',' O2',
WM(1)= 1.01, 2.02, 18.02, 16.00, 17.01, 32.00,
EPSI(1,1)= 37.00, 59.7, 809.10, 106.70, 79.80, 106.70,
SIGMA(1,1)= 2.7080, 2.8270, 2.6410, 3.0500, 3.1470, 3.4670,
SIGOF= 3.4670, 2.8720, WTMOL= 32.0000, 2.02,
EPSOF= 106.700, 59.700,
NR = 10,
R = 1., 2., 3., 4., 5., 6., 7., 8., 10., 20.,
NPRES= 3,
PRSS = 1500., 2500., 3500.,
TC1(1, 1)= 1759., 3236., 4424., 5343., 5983.,
6372., 6551., 6581., 6440., 5349.,
WMTAB(1, 1)= 4.032, 6.048, 8.056, 10.013, 11.846,
13.506, 14.956, 16.196, 18.188, 23.664,
YSP(1, 1, 1)= .000000, .000030, .001614, .009852, .022929,
.031661, .031861, .026813, .015668, .000825,
YSP(1, 2, 1)= .873999, .747972, .620726, .489511, .360462,
.248102, .163759, .108079, .051492, .003362,
YSP(1, 3, 1)= .126001, .251997, .377462, .497256, .599309,
.672288, .712143, .724610, .707180, .532970,
YSP(1, 4, 1)= .000000, .000000, .000000, .000041, .000607,
.003054, .007870, .013118, .018590, .006486,
YSP(1, 5, 1)= .000000, .000001, .000198, .003324, .016285,
.041593, .070814, .092679, .106480, .043571,
YSP(1, 6, 1)= .000000, .000000, .000000, .000017, .000398,
.003239, .013353, .034298, .099805, .411976,
TC1(1, 2)= 1759., 3236., 4428., 5367., 6044.,
6470., 6674., 6710., 6552., 5387.,
WMTAB(1, 2)= 4.032, 6.048, 8.058, 10.025, 11.885,
13.578, 15.058, 16.313, 18.302, 23.707,
FGAMT(1)= 1.3586, 1.2839, 1.2369, 1.1972, 1.1668,
1.1470, 1.1372, 1.1347, 1.1367, 1.1642,
YSP(1, 1, 2)= .000000, .000023, .001263, .007968, .019342,
.027595, .028109, .023458, .013244, .000624,
YSP(1, 2, 2)= .873999, .747978, .621002, .490751, .361940,
.247657, .160390, .103091, .047059, .002810,
YSP(1, 3, 2)= .126001, .251998, .377579, .498525, .603905,
.681730, .725494, .739105, .719344, .536197,
YSP(1, 4, 2)= .000000, .000000, .000000, .000027, .000439,
.002421, .006703, .011610, .016639, .005415,
YSP(1, 5, 2)= .000000, .000001, .000155, .002717, .014075,
.037924, .067268, .089856, .103502, .040315,
YSP(1, 6, 2)= .000000, .000000, .000000, .000011, .000289,
.002604, .011806, .032392, .099235, .413671,
TC1(1, 3)= 1759., 3236., 4430., 5381., 6080.,
6532., 6754., 6794., 6624., 5410.,
WMTAB(1, 3)= 4.032, 6.048, 8.059, 10.033, 11.908,
13.624, 15.125, 16.391, 18.376, 23.734,
YSP(1, 1, 3)= .000000, .000020, .001073, .006901, .017192,
.025071, .025768, .021375, .011778, .000516,
YSP(1, 2, 3)= .873999, .747981, .621152, .491454, .362826,
.247351, .158084, .099659, .044130, .002486,
YSP(1, 3, 3)= .126001, .251999, .377643, .499249, .606698,
.687788, .734389, .748857, .727371, .538200,
YSP(1, 4, 3)= .000000, .000000, .000000, .000020, .000350,
.002053, .005981, .010658, .015399, .004789,
YSP(1, 5, 3)= .000000, .000000, .000132, .002367, .012692,
.035437, .064720, .087774, .101290, .038201,
YSP(1, 6, 3)= .000000, .000000, .000000, .000008, .000231,
.002228, .010805, .031124, .098907, .414721,
NT = 6,
TTAB(1)= 540.00,1080.00,1980.00,3060.00,4860.00,7020.00,
VSP(1,1)= 0.4194, 0.6580, 0.9755, 1.2918, 1.7409, 2.2070,
VSP(1,2)= 0.4995, 0.7952, 1.1790, 1.5634, 2.1077, 2.6716,
VSP(1,3)= 0.6137, 1.2033, 2.2018, 3.2518, 4.6926, 6.1211,
VSP(1,4)= 1.0561, 1.7466, 2.6156, 3.4679, 4.6870, 5.9441,
VSP(1,5)= 1.1065, 1.7807, 2.6403, 3.5110, 4.7368, 6.0046,
VSP(1,6)= 1.1558, 1.9118, 2.8626, 3.7955, 5.1299, 6.5058,
CPTAB(1,1)= 4.968, 4.968, 4.968, 4.968, 4.968, 4.968,
CPTAB(1,2)= 6.995, 7.009, 7.307, 7.907, 8.637, 9.125,
CPTAB(1,3)= 8.028, 8.680, 10.163, 11.699, 13.122, 13.933,
CPTAB(1,4)= 5.234, 5.050, 4.994, 4.980, 4.990, 5.081,
CPTAB(1,5)= 6.965, 7.003, 7.422, 8.046, 8.666, 9.038,
CPTAB(1,6)= 7.023, 7.671, 8.438, 8.853, 9.388, 9.859,
NTL= 0, 0, NTFILM= 7, 0,
TFILM(1,1)= 180.00, 540.00,1080.00,1800.00,2700.00,3600.00,5400.00,
VVIS(1,1)= 0.45940,1.23790,2.04750,2.88240,3.74240,4.52090,5.88170,
KVAP(1,1)= 0.145, 0.393, 0.705, 1.125, 1.453, 1.809, 2.476,
CPVAP(1,1)= 0.217, 0.220, 0.240, 0.261, 0.273, 0.282, 0.298,
SEND

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PROPAN. MID

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$INPUT
PCRTT=731, 618,
FLAMEF= 2,          TFLAME=6379,
NAMES='LOX','PROPANE',
NSP= 5,
SPNAME= '    CH4','    CO','    CO2','    H2','    H2O',
WM(1)=    16.04,    28.01,    44.01,    2.02,    18.02,
EPSI(1,1)= 148.600,    91.700,    195.200,    59.700,    809.100,
SIGMA(1,1)= 3.7580,    3.6900,    3.9410,    2.8270,    2.6410,
SIGOF= 3.4670,    5.1180,    WTMOL= 32.0000, 44.1000,
EPSOF= 106.700, 237.100,
NPRE= 3,
PRSS= 500.000, 1000.000, 1500.000,
NR= 7,
R(1)=    0.30, 0.60, 0.80, 1.00, 1.20, 1.50, 2.00,
YSP(1, 1,1)= 0.66, 0.32, 0.17, 0.07, 0.00, 0.00, 0.00,
YSP(1, 2,1)= 0.26, 0.38, 0.40, 0.41, 0.42, 0.41, 0.38,
YSP(1, 3,1)= 0.01, 0.01, 0.01, 0.01, 0.01, 0.02, 0.06,
YSP(1, 4,1)= 0.07, 0.28, 0.41, 0.49, 0.53, 0.43, 0.27,
YSP(1, 5,1)= 0.00, 0.01, 0.01, 0.02, 0.04, 0.14, 0.29,
YSP(1, 1,2)= 0.66, 0.34, 0.19, 0.07, 0.02, 0.00, 0.00,
YSP(1, 2,2)= 0.26, 0.37, 0.39, 0.41, 0.41, 0.41, 0.39,
YSP(1, 3,2)= 0.02, 0.01, 0.01, 0.01, 0.01, 0.02, 0.06,
YSP(1, 4,2)= 0.06, 0.27, 0.39, 0.48, 0.52, 0.43, 0.27,
YSP(1, 5,2)= 0.00, 0.01, 0.02, 0.03, 0.04, 0.14, 0.29,
YSP(1, 1,3)= 0.68, 0.35, 0.20, 0.09, 0.02, 0.00, 0.00,
YSP(1, 2,3)= 0.25, 0.37, 0.39, 0.40, 0.41, 0.41, 0.37,
YSP(1, 3,3)= 0.02, 0.01, 0.01, 0.01, 0.01, 0.02, 0.06,
YSP(1, 4,3)= 0.05, 0.26, 0.38, 0.47, 0.51, 0.43, 0.27,
YSP(1, 5,3)= 0.00, 0.01, 0.02, 0.03, 0.05, 0.14, 0.30,
WMTAB(1,1)= 20.1, 16.7, 15.2, 14.3, 14.0, 15.7, 18.7,
WMTAB(1,2)= 20.3, 17.0, 15.5, 14.6, 14.2, 15.7, 18.7,
WMTAB(1,3)= 20.5, 17.2, 15.7, 14.7, 14.3, 15.7, 18.8,
TCI(1,1)= 1861, 2239, 2351, 2478, 2772, 3987, 5513,
TCI(1,2)= 1899, 2304, 2440, 2582, 2841, 3990, 5566,
TCI(1,3)= 1923, 2347, 2497, 2648, 2894, 3991, 5593,
FGAMT(1)= 1.13, 1.17, 1.19, 1.22, 1.26, 1.27, 1.20,
NT= 6,
TTAB(1)= 540.00,1080.00,1980.00,3060.00,4860.00,7020.00,
VSP(1,1)= 0.6277, 1.0780, 1.6370, 2.1770, 2.9420, 3.7350,
VSP(1,2)= 0.9939, 1.6320, 2.4160, 3.2090, 4.3320, 5.4930,
VSP(1,3)= 0.8512, 1.5200, 2.3500, 3.1490, 4.2450, 5.4020,
VSP(1,4)= 0.4194, 0.6580, 0.9755, 1.2918, 1.7409, 2.2070,
VSP(1,5)= 0.6137, 1.2033, 2.2018, 3.2518, 4.6926, 6.1211,
CPTAB(1,1)= 8.535, 12.484, 18.052, 21.580, 23.895, 24.855,
CPTAB(1,2)= 6.965, 7.275, 8.056, 8.533, 8.837, 8.986,
CPTAB(1,3)= 8.863, 11.266, 13.201, 14.145, 14.732, 15.022,
CPTAB(1,4)= 4.968, 4.968, 4.968, 4.968, 4.968, 4.968,
CPTAB(1,5)= 8.028, 8.680, 10.163, 11.699, 13.122, 13.933,
NTL= 1, 11,
TLI(1,2)= 180.00, 360.00, 420.00, 460.00, 490.00, 530.00, 560.00,
580.00, 600.00, 630.00, 666.,
PV(1,2)= 0.001, 5.650, 16.000, 37.810, 65.700,124.300,188.700,
243.400,308.400,426.000, 618.,
RHOL(1,2)= .025930,.021840,.020940,.020000,.019220,.018030,.017070,
.016380,.015630,.014010,.010,
CP(1,2)= 0.53000,0.53000,0.53600,0.55000,0.57700,0.63000,0.69000,
0.74500,0.82000,1.01500,5.5,
LAM(1,2)= 238.000,191.400,182.700,172.200,162.800,148.700,135.600,
125.800,114.300, 91.100,.01,
NTFLM= 1, 6,
TFILM(1,2)= 180.00, 360.00, 540.00, 600.00, 625.00, 650.00,
VVIS(1,2)= 0.15570,0.30970,0.48300,0.55800,0.62500,0.74200,
KVAP(1,2)= 0.023, 0.095, 0.255, 0.336, 0.387, 0.417,
CPVAP(1,2)= 0.208, 0.285, 0.381, 0.417, 0.432, 0.447,
$END

```

RP1.DAT

```

$INPUT
PCRT=731, 315,
FLAMEP= 2,          TFLAME=6458.,
NAMES='LOX', 'RP-1',
NFRS= 3,
NSP= 9,
SPNAME= '      CH4', '      CO', '      CO2', '      H', '      H2', '      H2O',
        '      O', '      O2', '      OH',
WM(1)= 16.04, 28.01, 44.01, 1.01, 2.02, 18.02, 16.00, 32.00, 17.01,
EPSI(1,1)= 148.600, 91.700, 195.200, 37.000, 59.700, 809.100, 106.700, 106.700, 79.800,
SIGMA(1,1)= 3.7580, 3.6900, 3.9410, 2.7080, 2.8270, 2.6410, 3.0500, 3.4670, 3.1470,
SIGOF= 3.4670, 7.5620, WTMOL= 32.0000, 172.000, FLAME2= F,
PRSS= 200.000, 250.000, 350.000, EPSOF= 106.700, 521.000,
NR= 6,
R(1)= 20.000, 10.000, 5.000, 2.400, 1.000, 0.100,
YSP(1,1,1)= 0.0, 0.0, 0.0, 0.0, 0.0099, 0.5470,
YSP(1,2,1)= 0.0000, 0.0086, 0.1087, 0.3465, 0.4679, 0.0080,
YSP(1,3,1)= 0.1082, 0.1935, 0.2220, 0.1202, 0.0024, 0.0070,
YSP(1,4,1)= 0.0000, 0.0007, 0.0130, 0.0433, 0.0000,
YSP(1,5,1)= 0.0000, 0.0012, 0.0165, 0.1102, 0.5132, 0.3239,
YSP(1,6,1)= 0.1064, 0.1841, 0.2602, 0.3017, 0.0066, 0.1139,
YSP(1,7,1)= 0.0000, 0.0093, 0.0403, 0.0123,
YSP(1,8,1)= 0.7850, 0.5759, 0.2540, 0.0133,
YSP(1,9,1)= 0.0003, 0.0247, 0.0851, 0.0524,
YSP(1,1,2)= 0.0, 0.0, 0.0, 0.0, 0.0117, 0.5586,
YSP(1,2,2)= 0.0000, 0.0080, 0.1070, 0.3468, 0.4676, 0.0081,
YSP(1,3,2)= 0.1082, 0.1942, 0.2247, 0.1212, 0.0028, 0.0071,
YSP(1,4,2)= 0.0000, 0.0006, 0.0123, 0.0415, 0.0000,
YSP(1,5,2)= 0.0000, 0.0011, 0.0160, 0.1099, 0.5103, 0.3114,
YSP(1,6,2)= 0.1064, 0.1847, 0.2620, 0.3045, 0.0076, 0.1147,
YSP(1,7,2)= 0.0000, 0.0087, 0.0390, 0.0116,
YSP(1,8,2)= 0.7850, 0.5766, 0.2540, 0.0127,
YSP(1,9,2)= 0.0003, 0.0260, 0.0848, 0.0517,
YSP(1,1,3)= 0.0, 0.0, 0.0, 0.0, 0.0148, 0.5763,
YSP(1,2,3)= 0.0000, 0.0073, 0.1042, 0.3471, 0.4673, 0.0082,
YSP(1,3,3)= 0.1082, 0.1952, 0.0229, 0.1228, 0.0033, 0.0072,
YSP(1,4,3)= 0.0, 0.0005, 0.0113, 0.0388, 0.0000,
YSP(1,5,3)= 0.0000, 0.0010, 0.0154, 0.1093, 0.5052, 0.2923,
YSP(1,6,3)= 0.1064, 0.1857, 0.2646, 0.0309, 0.0094, 0.1160,
YSP(1,7,3)= 0.0000, 0.0078, 0.0371, 0.0106,
YSP(1,8,3)= 0.7851, 0.5775, 0.2540, 0.0119,
YSP(1,9,3)= 0.0003, 0.0249, 0.0844, 0.0506,
WMTAB(1,1)= 31.8060, 31.1100, 27.7770, 22.2140, 14.3660, 12.0140,
WMTAB(1,2)= 31.8060, 31.1370, 27.8500, 22.2730, 14.4120, 12.1050,
WMTAB(1,3)= 31.8070, 31.1750, 27.9610, 22.3630, 14.4950, 12.2420,
TC1(1,1)= 3133.50, 4960.10, 5958.60, 6144.90, 2662.30, 1596.00,
TC1(1,2)= 3133.70, 4978.50, 6009.60, 6198.40, 2679.90, 1612.40,
TC1(1,3)= 3133.90, 5005.20, 6086.90, 6278.90, 2709.80, 1636.90,
PGMNT(1)= 1.255, 1.218, 1.209, 1.223, 1.262, 1.296,
MT= 6,
TTAB(1)= 540.00, 1080.00, 1980.00, 3060.00, 4860.00, 7020.00,
VSP(1,1)= 0.6277, 1.0780, 1.6370, 2.1770, 2.9420, 3.7350,
VSP(1,2)= 0.9939, 1.6230, 2.4160, 3.2090, 4.3320, 5.4930,
VSP(1,3)= 0.8512, 1.5200, 2.3500, 3.1490, 4.2450, 5.4020,
VSP(1,4)= 0.4194, 0.6580, 0.9755, 1.2918, 1.7409, 2.2070,
VSP(1,5)= 0.4995, 0.7952, 1.1790, 1.5634, 2.1077, 2.6716,
VSP(1,6)= 0.6137, 1.2033, 2.2018, 3.2518, 4.6926, 6.1211,
VSP(1,7)= 1.0561, 1.7466, 2.6156, 3.4679, 4.6870, 5.9441,
VSP(1,8)= 1.1558, 1.9118, 2.8626, 3.7955, 5.1299, 6.5058,
VSP(1,9)= 1.1065, 1.7807, 2.6403, 3.5110, 4.7368, 6.0046,
CPTAB(1,1)= 8.535, 12.484, 18.052, 21.580, 23.895, 24.855,
CPTAB(1,2)= 6.965, 7.275, 8.056, 8.533, 8.837, 8.986,
CPTAB(1,3)= 8.863, 11.266, 13.201, 14.145, 14.732, 15.022,
CPTAB(1,4)= 4.968, 4.968, 4.968, 4.968, 4.968, 4.968,
CPTAB(1,5)= 6.995, 7.009, 7.307, 7.907, 8.637, 9.125,
CPTAB(1,6)= 8.028, 8.680, 10.163, 11.699, 13.122, 13.933,
CPTAB(1,7)= 5.234, 5.050, 4.994, 4.980, 4.990, 5.081,
CPTAB(1,8)= 7.023, 7.671, 8.438, 8.853, 9.388, 9.859,
CPTAB(1,9)= 6.965, 7.003, 7.422, 8.046, 8.666, 9.038,
NTL= 1, 10,
TLI(1,2)= 460.00, 530.00, 560.00, 660.00, 760.00, 860.00,
960.00, 1060.00, 1160.00, 1218.00,
FV(1,2)= 0.002, 0.003, 0.010, 0.210, 2.100, 11.000,
36.000, 100.000, 220.000, 315.000,
REOL(1,2)= .029740, .028870, .028410, .027200, .025640, .023900,
.022000, .019560, .015740, .009840,
CP(1,2)= 0.43500, 0.47000, 0.48500, 0.54000, 0.59000, 0.64700,
0.70000, 0.77500, 0.86000, 0.90100,
LAM(1,2)= 144.300, 139.200, 137.000, 128.900, 120.000, 109.800,
97.770, 82.660, 60.740,
MTFILM= 7,
TFILM(1,1)= 180.00, 540.00, 1080.00, 1800.00, 2700.00, 3600.00, 5400.00,
TFILM(1,2)= 360.00, 540.00, 720.00, 900.00, 1080.00, 1260.00,
VVIS(1,1)= 0.45940, 1.23790, 2.04750, 2.88240, 3.74240, 4.52090, 5.88170,
VVIS(1,2)= 0.15700, 0.24600, 0.33600, 0.42000, 0.48200, 0.53800,
KVAP(1,1)= 0.145, 0.393, 0.705, 1.125, 1.453, 1.809, 2.476,
KVAP(1,2)= 0.126, 0.174, 0.278, 0.394, 0.498, 0.607,
CPVAP(1,1)= 0.217, 0.220, 0.240, 0.261, 0.273, 0.282, 0.298,
CPVAP(1,2)= 0.275, 0.380, 0.470, 0.562, 0.650, 0.725,
$END

```

UDMH.DAT

```
$INPUT
PCRT= 1470, 867,
NAMES='N2O4', 'UDMH',
NSP=11,
SPNAME= '      ' H' '      H2' '      H2O' '      N2' '      CO' '      CO2',
          '      ' HO' '      O2' '      NO' '      O' '      CH4',
WM(1)= 1.00, 2.00, 18.00, 28.00, 28.00, 44.00, 17.00, 32.00, 30.00, 16.00, 16.00,
EPSI(1,1)= 37.000, 59.700, 809.000, 71.400, 91.700, 195.000, 79.800, 106.700, 116.700, 106.700, 148.600,
SIGMA(1,1)= 2.7100, 2.8300, 2.6400, 3.8000, 3.6900, 3.9400, 3.1500, 3.4700, 3.4900, 3.0500, 3.7600,
SIGOF= 3.9690, 4.68, WTMOL= 46.0000, 60.0000,
NPRES= 3,
PRSS= 100.000, 300.000, 1000.000, EPSOF= 331.900, 432.000,
NR= 10,
R(1)= 15.000, 10.000, 5.000, 2.000, 1.600, 1.000, 0.500, 0.200, 0.100, 0.080,
YSP(1, 1,1)= 0.0, 0.0, 0.0044, 0.0279, 0.0150, 0.0002,
YSP(1, 2,1)= 0.0, 0.0001, 0.0085, 0.1461, 0.2488, 0.4517, 0.5200, 0.4858, 0.4635, 0.4580,
YSP(1, 3,1)= 0.1233, 0.1748, 0.2669, 0.2970, 0.2339, 0.0708, 0.0081, 0.0182, 0.0162, 0.0146,
YSP(1, 4,1)= 0.3318, 0.3268, 0.3070, 0.2679, 0.2515, 0.2160, 0.1880, 0.1789, 0.1805, 0.1815,
YSP(1, 5,1)= 0.0, 0.0002, 0.0279, 0.1832, 0.2164, 0.2520, 0.1739, 0.0603, 0.0260, 0.0199,
YSP(1, 6,1)= 0.0617, 0.0882, 0.1222, 0.0504, 0.0297, 0.0093, 0.0016, 0.0021, 0.0010, 0.0008,
YSP(1, 7,1)= 0.0003, 0.0039, 0.0447, 0.0203, 0.0040,
YSP(1, 8,1)= 0.4798, 0.3934, 0.1778, 0.0019,
YSP(1, 9,1)= 0.0029, 0.0121, 0.0261, 0.0030, 0.0004,
YSP(1,10,1)= 0.0, 0.0004, 0.0142, 0.0023, 0.0002,
YSP(1,11,1)= 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0194, 0.0645, 0.0991, 0.1087,
YSP(1, 1,2)= 0.0, 0.0, 0.0029, 0.0207, 0.0100, 0.0001,
YSP(1, 2,2)= 0.0, 0.0001, 0.0067, 0.1464, 0.2510, 0.4517, 0.5006, 0.4577, 0.4325, 0.4266,
YSP(1, 3,2)= 0.1234, 0.1748, 0.2735, 0.3058, 0.2365, 0.0708, 0.0127, 0.0211, 0.0176, 0.0157,
YSP(1, 4,2)= 0.3318, 0.3268, 0.3080, 0.2701, 0.2524, 0.2160, 0.1938, 0.1878, 0.1905, 0.1917,
YSP(1, 5,2)= 0.0, 0.0002, 0.0229, 0.1843, 0.2174, 0.2520, 0.1738, 0.0616, 0.0272, 0.0211,
YSP(1, 6,2)= 0.0617, 0.0882, 0.1282, 0.0511, 0.0296, 0.0093, 0.0023, 0.0021, 0.0010, 0.0007,
YSP(1, 7,2)= 0.0002, 0.0039, 0.0410, 0.0165, 0.0028,
YSP(1, 8,2)= 0.4798, 0.3934, 0.1766, 0.0012,
YSP(1, 9,2)= 0.0029, 0.0121, 0.0288, 0.0026, 0.0003,
YSP(1,10,2)= 0.0, 0.0004, 0.0108, 0.0014, 0.0001,
YSP(1,11,2)= 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0357, 0.0928, 0.1328, 0.1433,
YSP(1, 1,3)= 0.0, 0.0, 0.0018, 0.0142, 0.0061, 0.0001,
YSP(1, 2,3)= 0.0, 0.0, 0.0049, 0.1465, 0.2527, 0.4513, 0.4698, 0.4185, 0.3905, 0.3839,
YSP(1, 3,3)= 0.1234, 0.1753, 0.2804, 0.3143, 0.2385, 0.0710, 0.0188, 0.0248, 0.0196, 0.0173,
YSP(1, 4,3)= 0.3318, 0.3269, 0.3090, 0.2723, 0.2531, 0.2160, 0.2033, 0.2001, 0.2039, 0.2053,
YSP(1, 5,3)= 0.0, 0.0001, 0.0176, 0.1853, 0.2181, 0.2520, 0.1757, 0.0635, 0.0286, 0.0222,
YSP(1, 6,3)= 0.0617, 0.0883, 0.1347, 0.0518, 0.0295, 0.0093, 0.0031, 0.0023, 0.0010, 0.0007,
YSP(1, 7,3)= 0.0002, 0.0029, 0.0364, 0.0123, 0.0017,
YSP(1, 8,3)= 0.4798, 0.3937, 0.1754, 0.0006,
YSP(1, 9,3)= 0.0029, 0.0122, 0.0316, 0.0020, 0.0002,
YSP(1,10,3)= 0.0, 0.0002, 0.0077, 0.0007,
YSP(1,11,3)= 0.0, 0.0, 0.0, 0.0, 0.0, 0.0001, 0.0623, 0.1326, 0.1781, 0.1899,
TC1(1,1)= 3041.00, 3969.00, 5272.00, 5516.00, 5023.00, 3455.00, 2293.00, 2008.00, 1911.00, 1890.00,
TC1(1,2)= 3041.00, 3931.00, 5418.00, 5673.00, 5093.00, 3456.00, 2406.00, 2139.00, 2040.00, 2019.00,
TC1(1,3)= 3041.00, 3990.00, 5564.00, 5821.00, 5147.00, 3458.00, 2563.00, 2300.00, 2195.00, 2172.00,
WMTAB(1,1)= 29.6800, 29.2100, 27.0600, 21.0600, 19.2300, 15.7000, 12.7900, 11.4200, 11.2200, 11.2100,
WMTAB(1,2)= 29.6800, 29.2200, 27.2600, 21.2200, 19.3000, 15.7100, 13.1900, 12.0000, 11.8500, 11.8500,
WMTAB(1,3)= 29.6900, 29.2300, 27.4600, 21.3700, 19.3400, 15.7100, 13.8500, 12.8100, 12.7100, 12.7100,
FGAMT(1)= 1.258, 1.215, 1.140, 1.162, 1.208, 1.293, 1.230, 1.188, 1.182, 1.181,
NT= 6,
TTAB(1)= 540.00, 1080.00, 1980.00, 3060.00, 4860.00, 7020.00,
VSP(1,1)= 0.4190, 0.6580, 0.9760, 1.2920, 1.7140, 2.2070,
VSP(1,2)= 0.5000, 0.7950, 1.1790, 1.5640, 2.1080, 2.6720,
VSP(1,3)= 0.6140, 1.2030, 2.2020, 3.2520, 4.6930, 6.1210,
VSP(1,4)= 0.9950, 1.5980, 2.3670, 3.1460, 4.2420, 5.3780,
VSP(1,5)= 0.9940, 1.6230, 2.4160, 3.2090, 4.3320, 5.4930,
VSP(1,6)= 0.8510, 1.5200, 2.3500, 3.1490, 4.2450, 5.4020,
VSP(1,7)= 1.1020, 1.7810, 2.6400, 3.5110, 4.7370, 6.0040,
VSP(1,8)= 1.1560, 1.9120, 2.8630, 3.7960, 5.1300, 6.5060,
VSP(1,9)= 1.0750, 1.7950, 2.6970, 3.5710, 4.8330, 6.1300,
VSP(1,10)= 1.0560, 1.7470, 2.6160, 3.4680, 4.6870, 5.9440,
VSP(1,11)= 0.6280, 1.0780, 1.6370, 2.1770, 2.9420, 3.7350,
CPTAB(1,1)= 2.500, 2.500, 2.500, 2.500, 2.500, 2.500,
CPTAB(1,2)= 7.000, 7.050, 7.350, 7.990, 8.620, 9.110,
CPTAB(1,3)= 8.080, 8.730, 10.220, 11.750, 13.200, 14.010,
CPTAB(1,4)= 7.000, 7.240, 8.000, 8.510, 8.850, 8.990,
CPTAB(1,5)= 7.000, 7.300, 8.100, 8.600, 8.910, 9.050,
CPTAB(1,6)= 8.940, 11.350, 13.290, 14.340, 14.830, 15.130,
CPTAB(1,7)= 7.000, 7.040, 7.460, 8.090, 8.730, 9.100,
CPTAB(1,8)= 7.070, 7.700, 8.470, 8.890, 9.440, 9.920,
CPTAB(1,9)= 7.170, 7.500, 8.280, 8.690, 8.970, 9.120,
CPTAB(1,10)= 5.260, 5.090, 5.020, 5.010, 5.020, 5.120,
CPTAB(1,11)= 8.570, 12.560, 18.150, 21.700, 24.000, 25.000,
NTL= 10, 10,
TLI(1,1)= 400.00, 440.00, 480.00, 520.00, 560.00, 600.00, 640.00, 680.00, 720.00, 760.00,
TLI(1,2)= 500.00, 550.00, 600.00, 650.00, 700.00, 750.00, 800.00, 850.00, 900.00, 940.00,
PV(1,1)= 0.270, 0.850, 3.940, 11.800, 30.000, 80.000, 180.000, 330.000, 660.000, 1200.00,
PV(1,2)= 1.160, 4.840, 13.540, 33.800, 73.500, 140.000, 235.000, 382.000, 617.000, 823.000,
RHOL(1,1)= .058000, .055600, .054100, .052700, .050850, .048700, .046300, .043500, .039350, .032400,
RHOL(1,2)= .029400, .028000, .026700, .025300, .023900, .022500, .021200, .019800, .018400, .015600,
CP(1,1)= 0.35000, 0.35000, 0.35300, 0.37200, 0.38800, 0.41400, 0.46400, 0.54300, 0.70000, 0.87000,
CP(1,2)= 0.65300, 0.67700, 0.70200, 0.72600, 0.75100, 0.77500, 0.80000, 0.82400, 0.84900, 0.86900,
LAM(1,1)= 435.000, 430.000, 422.000, 412.000, 403.000, 392.000, 379.000, 365.000, 346.000, 315.000,
LAM(1,2)= 302.500, 288.000, 269.000, 245.400, 221.000, 192.300, 156.900, 118.800, 72.100, 26.300,
NTFLM= 7, 6,
TFILM(1,1)= 400.00, 600.00, 1000.00, 1600.00, 2400.00, 3200.00, 4000.00,
TFILM(1,2)= 400.00, 800.00, 1200.00, 2000.00, 2800.00, 4000.00,
VVIS(1,1)= 0.62400, 0.92000, 1.57000, 2.34000, 3.21000, 3.91000, 4.57000,
VVIS(1,2)= 0.33600, 0.36800, 0.40000, 0.46400, 0.52800, 0.62400,
KVAP(1,1)= 0.0940, 0.2240, 0.4850, 0.8750, 1.3900, 1.9100, 2.4400,
KVAP(1,2)= 0.1628, 0.3336, 0.5044, 0.8460, 1.1876, 1.7000,
CPVAP(1,1)= 0.231, 0.238, 0.253, 0.269, 0.286, 0.297, 0.300,
CPVAP(1,2)= 0.580, 0.610, 0.640, 0.700, 0.761, 0.852,
$END
```

APPENDIX B

Lox Properties

LOX Properties:

In order to increase computational accuracy and to reduce the required amount of input, curve fits for liquid and gaseous oxygen physical properties are included in the source code. The program searches through the list of propellant names, and if the name LOX is found, then the table interpolation is skipped and built-in curve fits are used. Except for LOX viscosity which is supplied as a table, all of the oxygen properties required by the code are curve fit. The required properties are listed below:

1	Vapor Pressure	(PSIA)
2	Boiling Temperature	(°R)
3	Liquid Density	(lbm/in ³)
4	Liquid Viscosity	(lbm/in-s)
5	Surface Tension	(lbs/in)
6	Liquid Specific Heat	(BTU/lbm-°R)
7	Heat of Vaporization	(BTU/lbm)
8	Vapor Viscosity	(lbm/in-s)
9	Vapor Conductivity	(BTU/in-s-°R)
10	Vapor Specific Heat	(BTU/lbm-°R)

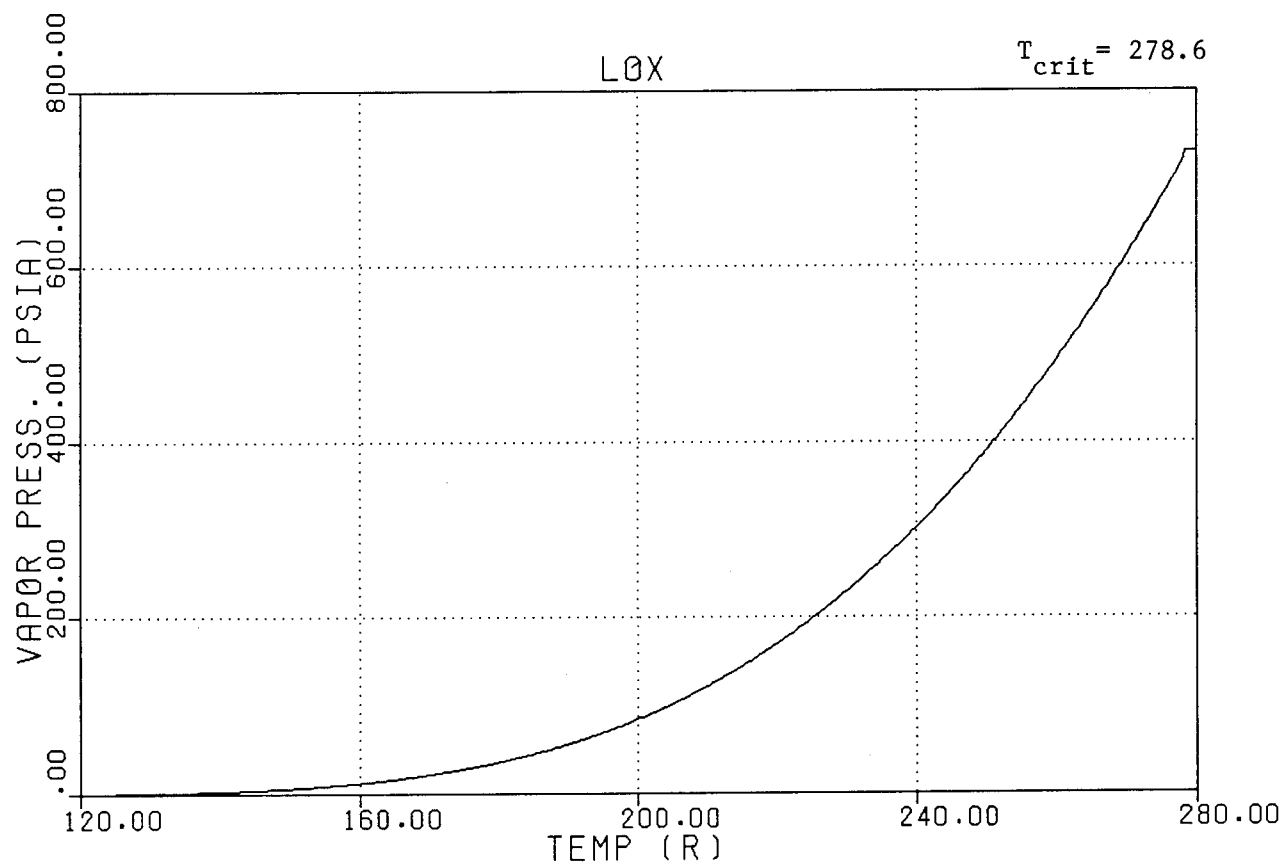
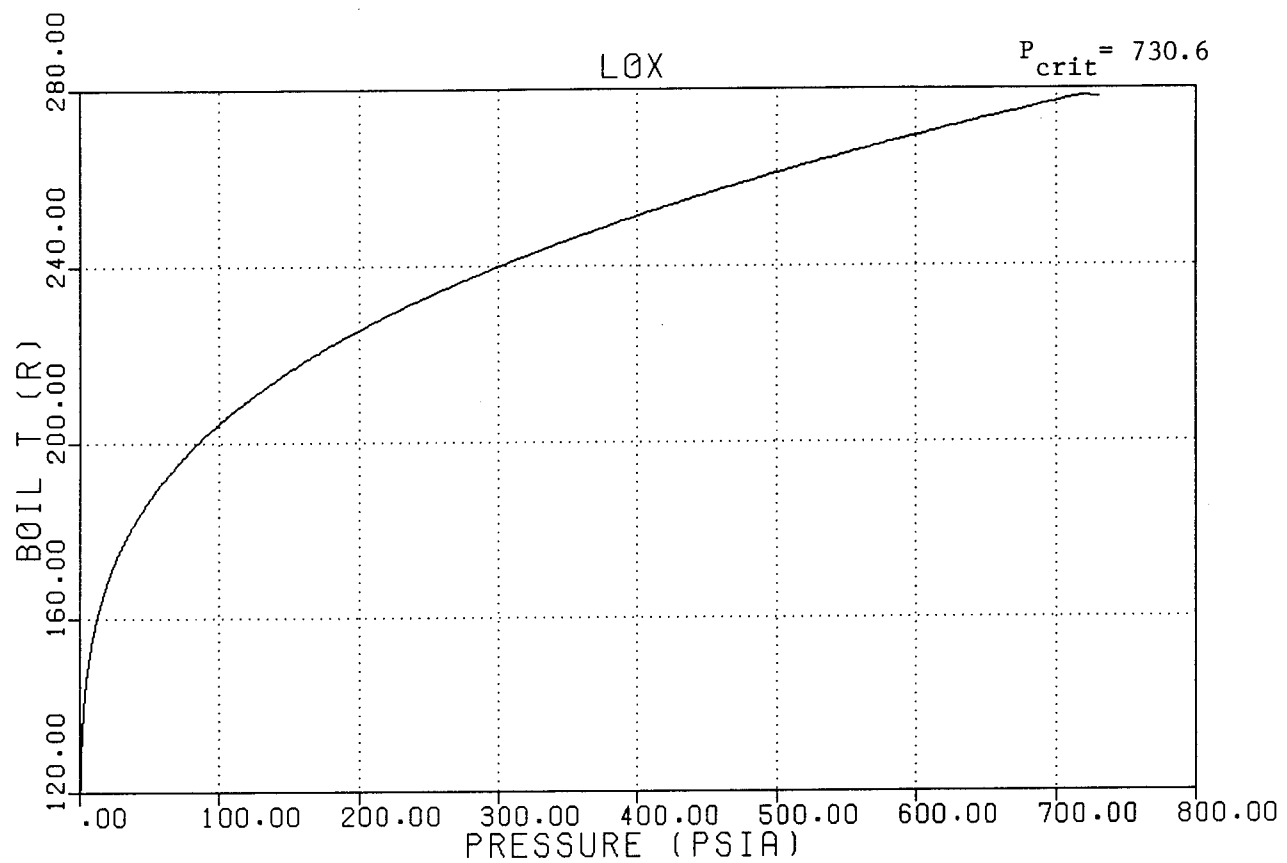
Table 1 of Appendix B gives the curve fit equations. Fits for items 1, 2, 3, 6, 8, 9, and 10 were taken from NASA TR R-67. The heat of vaporization, λ , curve fit in that report gave a poor result near the critical temperature. The heat of vaporization curve fit used here was derived by G. Nickerson by fitting a graphical representation of λ vs T given in Aerojet Report No. 9050-111-65. The table used for liquid viscosity and the curve fit used for surface tension (items 4 and 5) were taken from the ROCCID code, NASA CR 1087109.

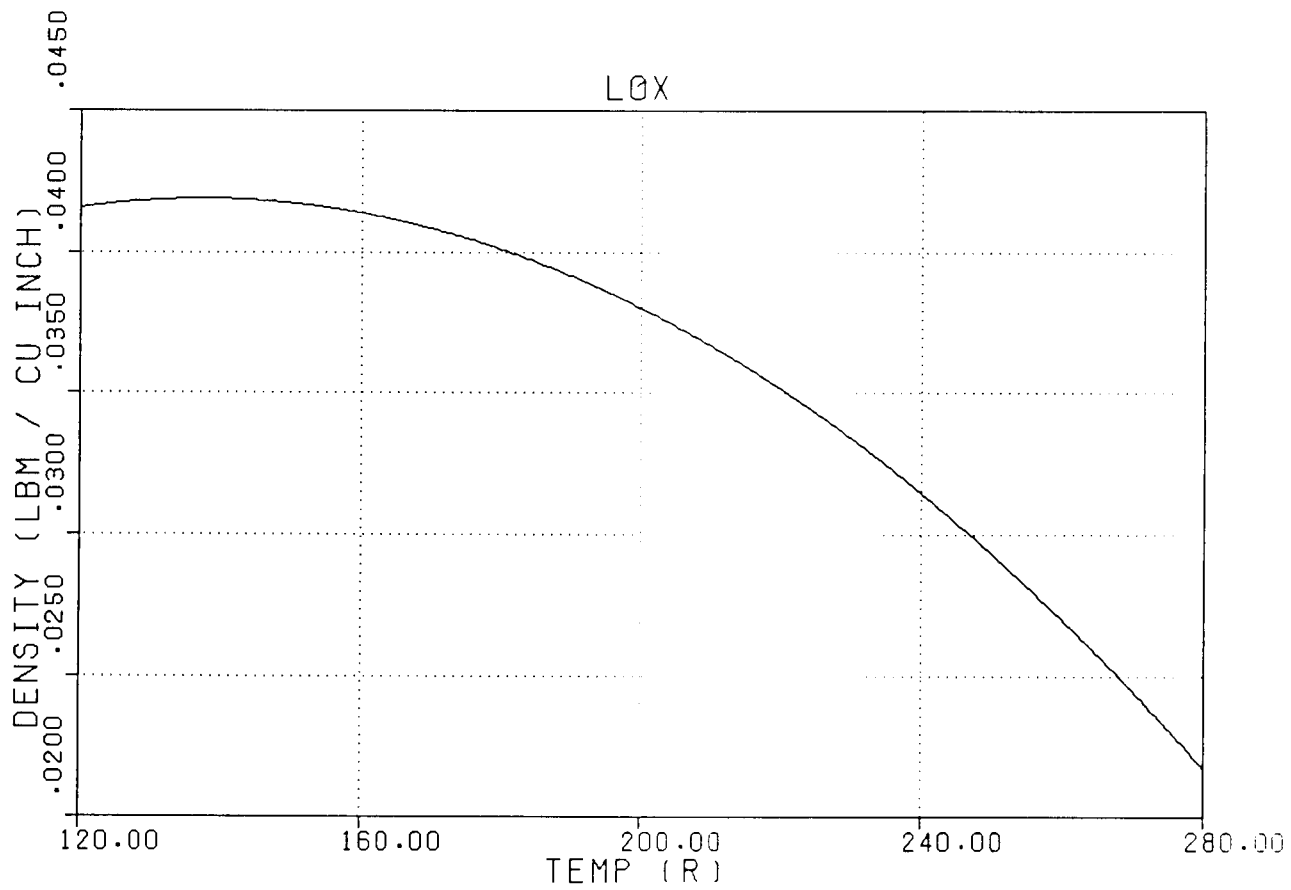
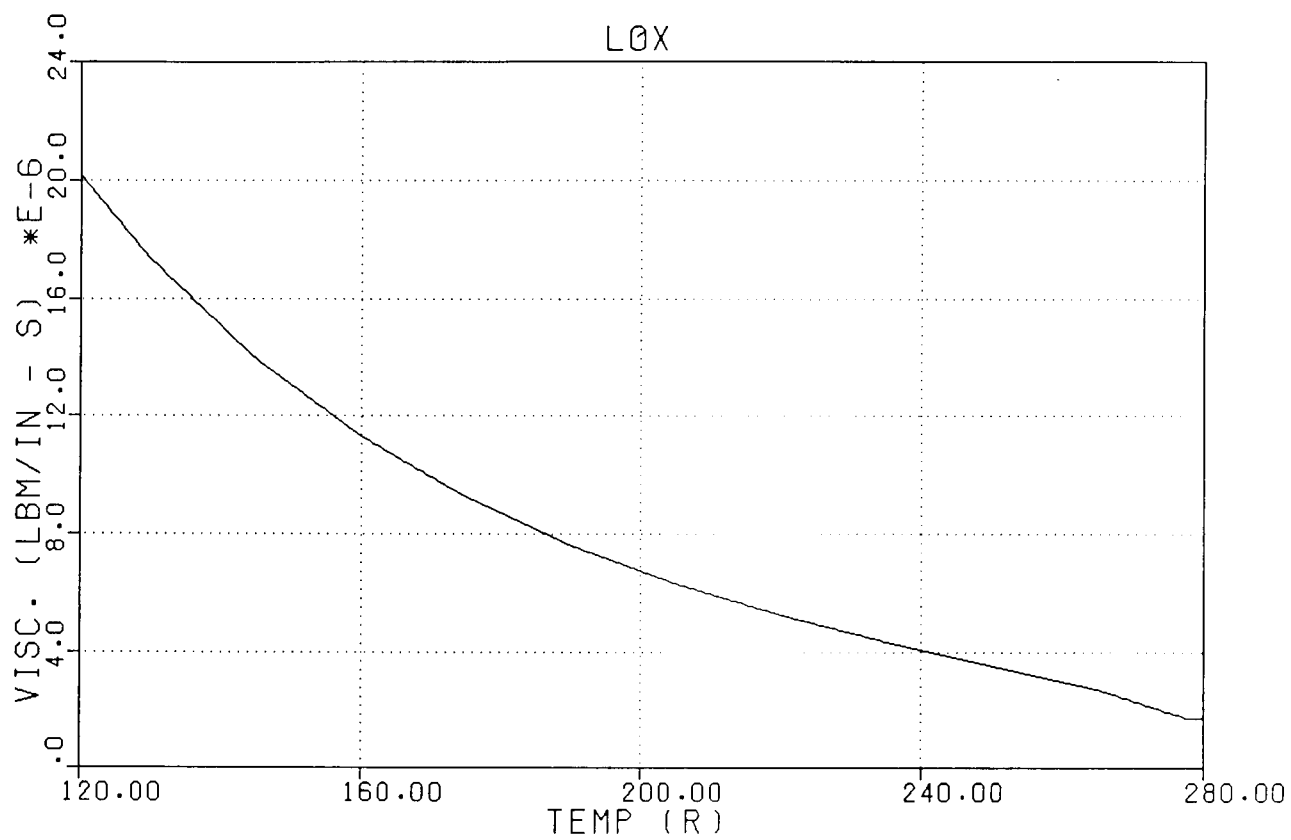
The properties listed above can be plotted for any propellant by setting the \$SCAP namelist variable PLTPROP = TRUE. The temperature range over which the liquid and vapor properties are plotted is taken from the first and last entries in the TLI and TFILM arrays of the \$INPUT namelist.

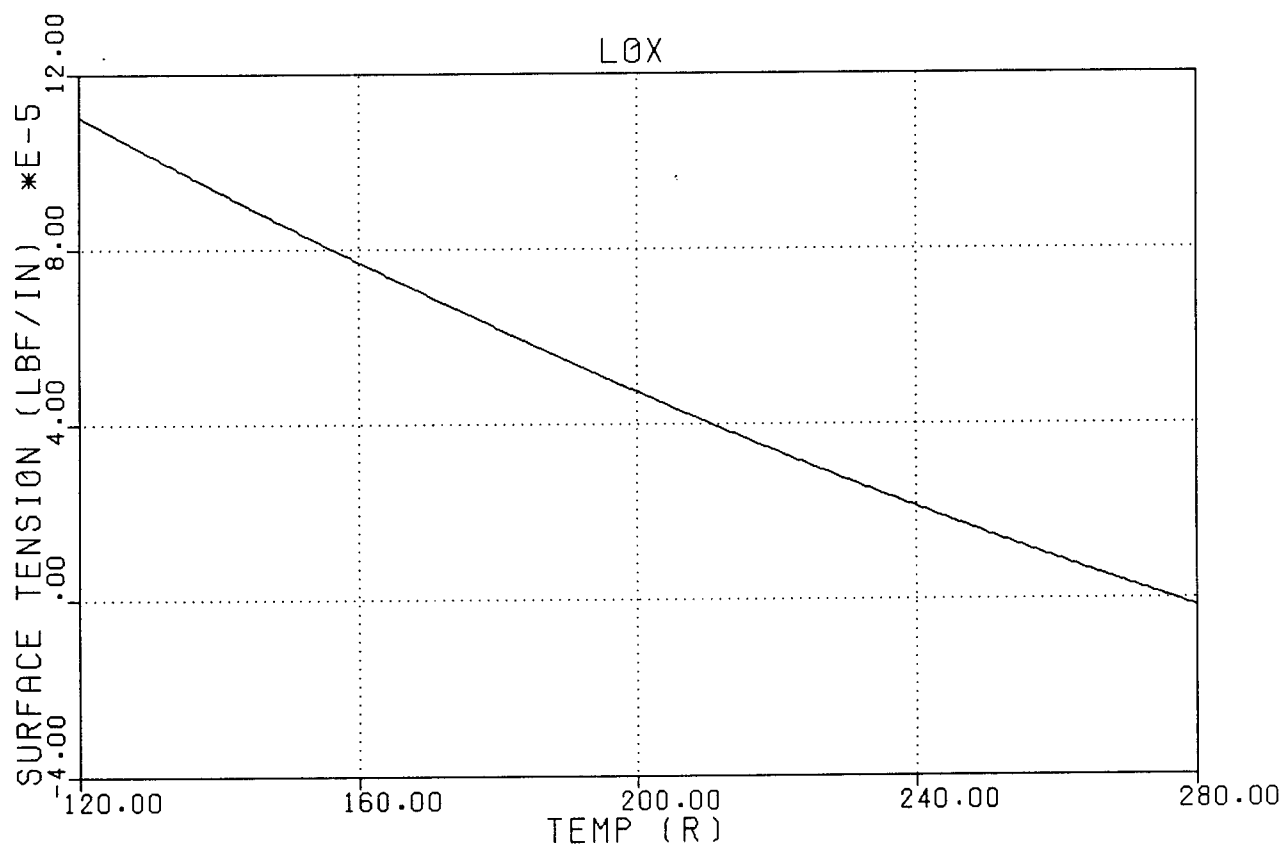
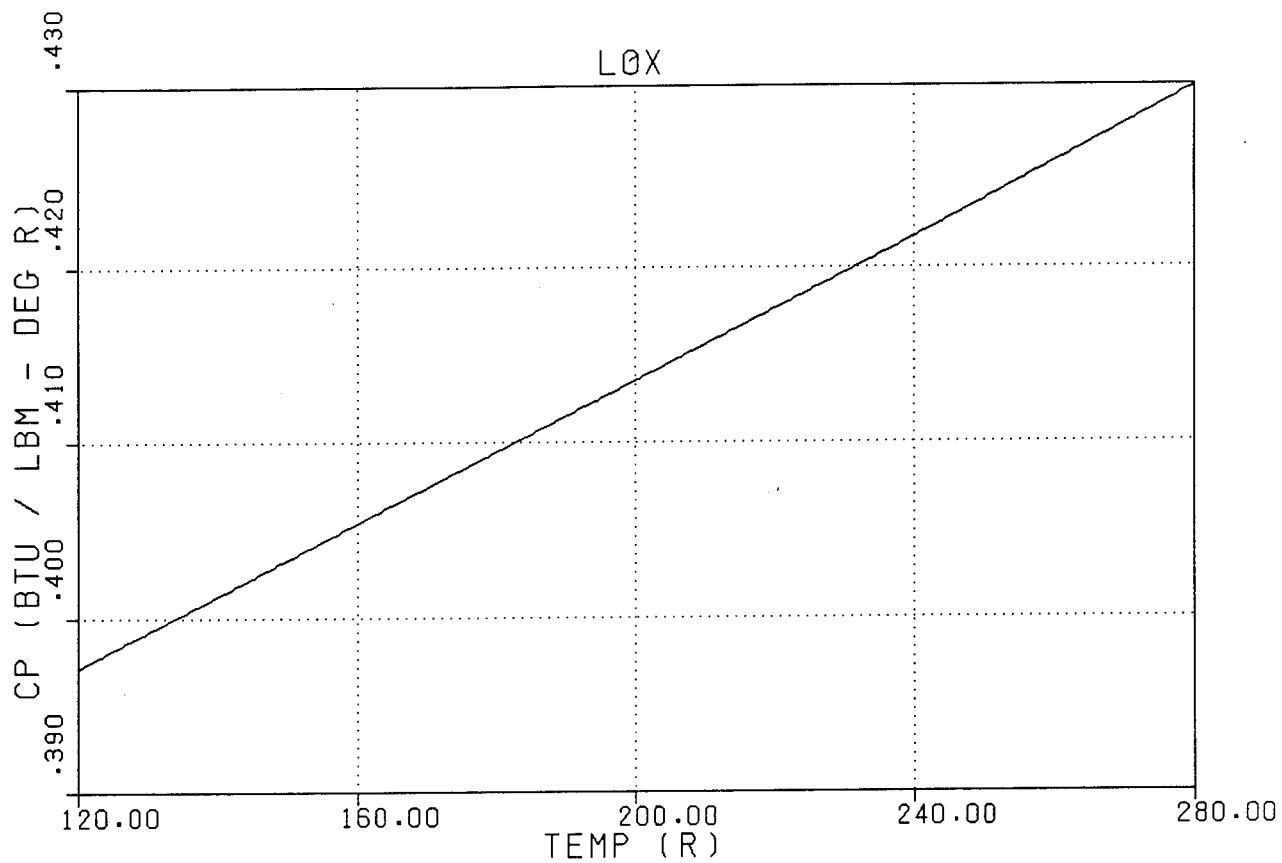
Plots are given here for the liquid and vapor properties of oxygen. For reference purposes a temperature entropy diagram for oxygen is included here for the low temperature range, i.e. 150°R.

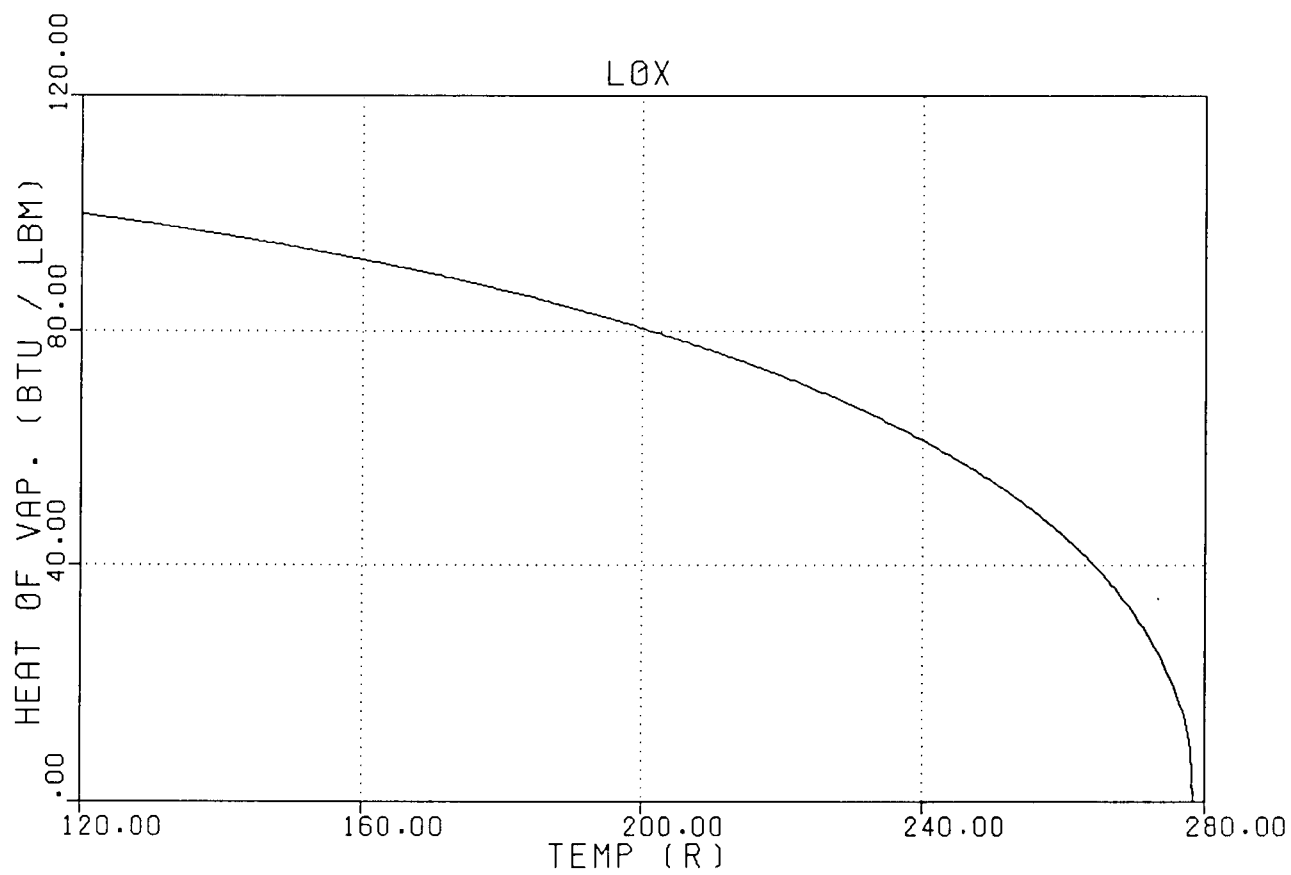
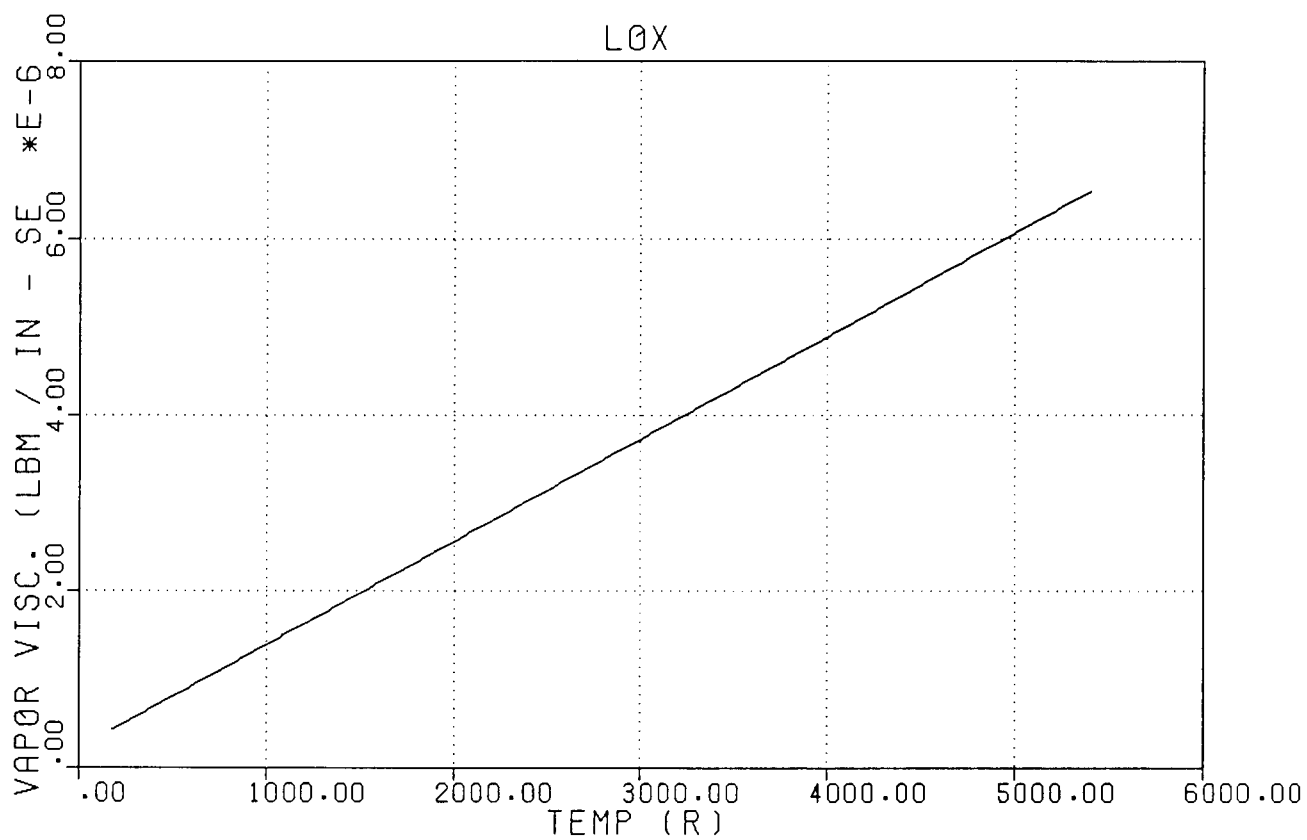
Table B-1. Physical Properties for Oxygen

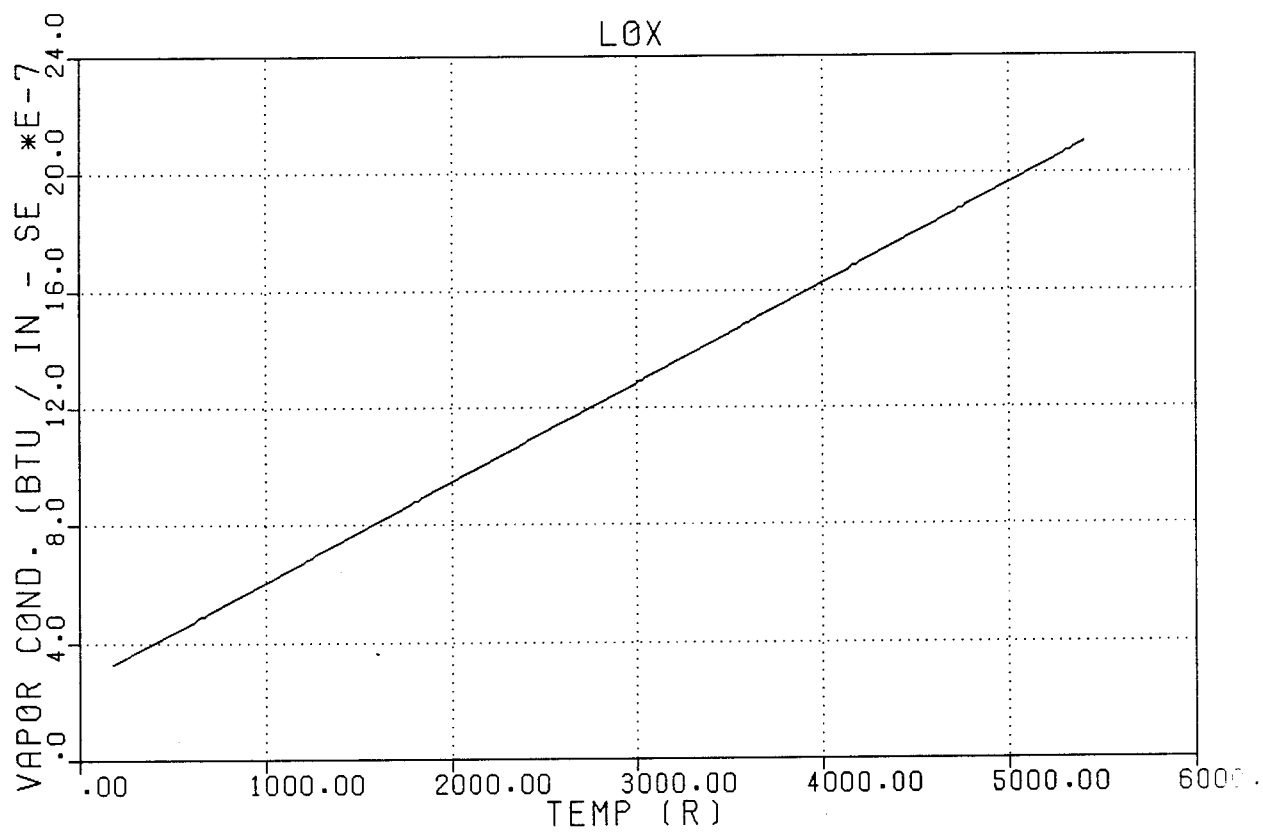
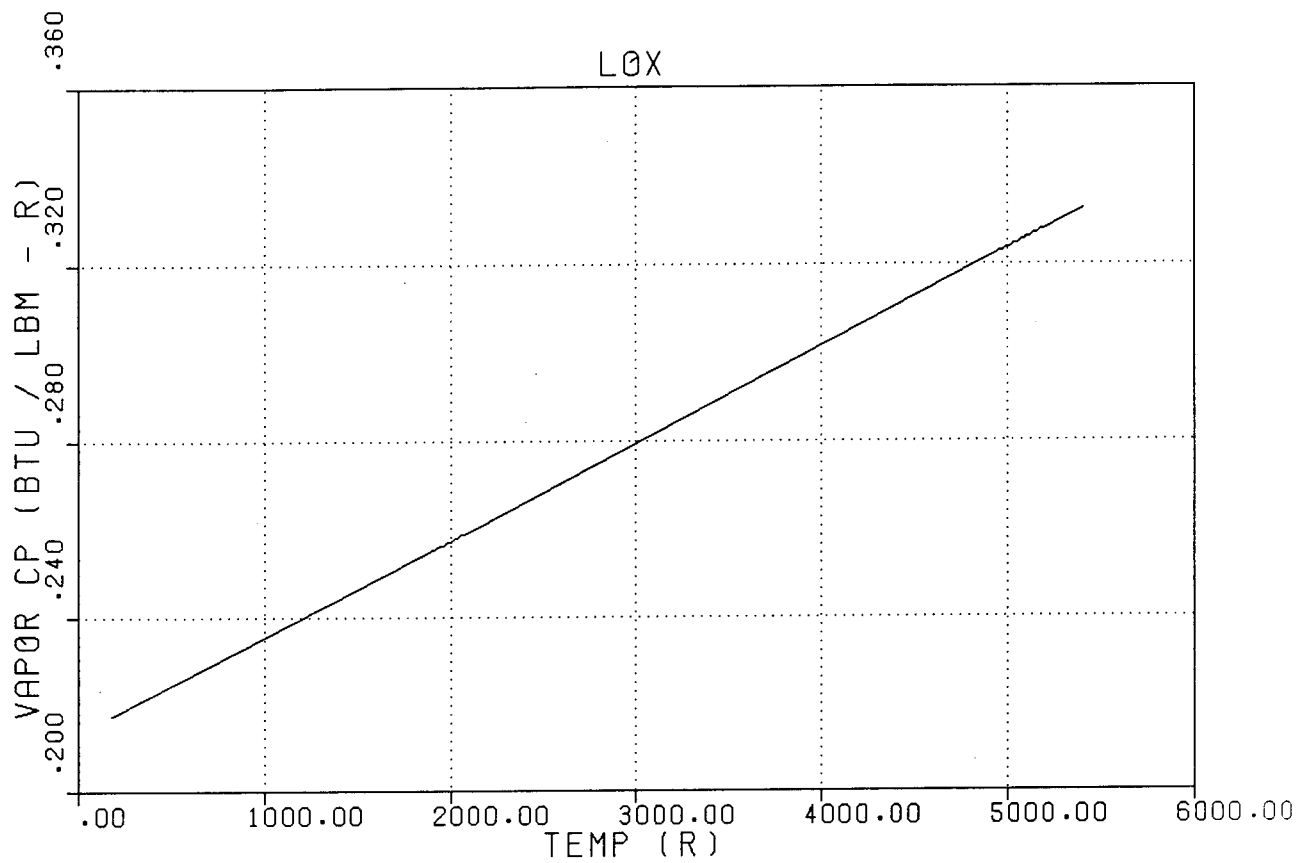
1,2	Vapor pressure	$\ln P_{a,s}$	$= 11.9584 - \frac{1473.4912}{T_L - 3.5680}$, lb/sq in
3	Density of liquid	ρ_L	$= 0.023079 + 2.7359 \times 10^{-4} T_L$ $- 9.9465 \times 10^{-7} T_L^2$, lb/cu in
4	Viscosity of liquid oxygen	μ_L	Given as a table, see plot lb/(in-sec)
5	Surface tension	σ_L	$= 2.77342 \times 10^{-3} - 1.36508 \times 10^{-5} T_L$ $+ 1.31254 \times 10^{-8} T_L^2$, lb/(in-sec)
6	Specific heat of liquid	$C_{p,L}$	$= 0.3726 + 2.0482 \times 10^{-4} T_L$, BTU/(lb°R)
7	Heat of vaporization	λ	$= 11.67(T_{crit} - T)^{1/2} - 2.81(T_{crit} - T)$ $- .00136(T_{crit} - T)^{3/2}$, BTU/lb
		T_{crit}	$= 278.6$, °R
8	Viscosity of oxygen vapor	μ_a	$= 2.2500 \times 10^{-7} + 1.1702 \times 10^{-9} \bar{T}$, lb/(in-sec)
9	Thermal conductivity of oxygen vapor	k_a	$= 2.6611 \times 10^{-7} + 3.4057 \times 10^{-10} \bar{T}$, BTU/(in-sec°R)
10	Specific heat of oxygen vapor	$C_{p,a}$	$= 0.21333 + 2.2111 \times 10^{-5} \bar{T}$, BTU/(lb°R)

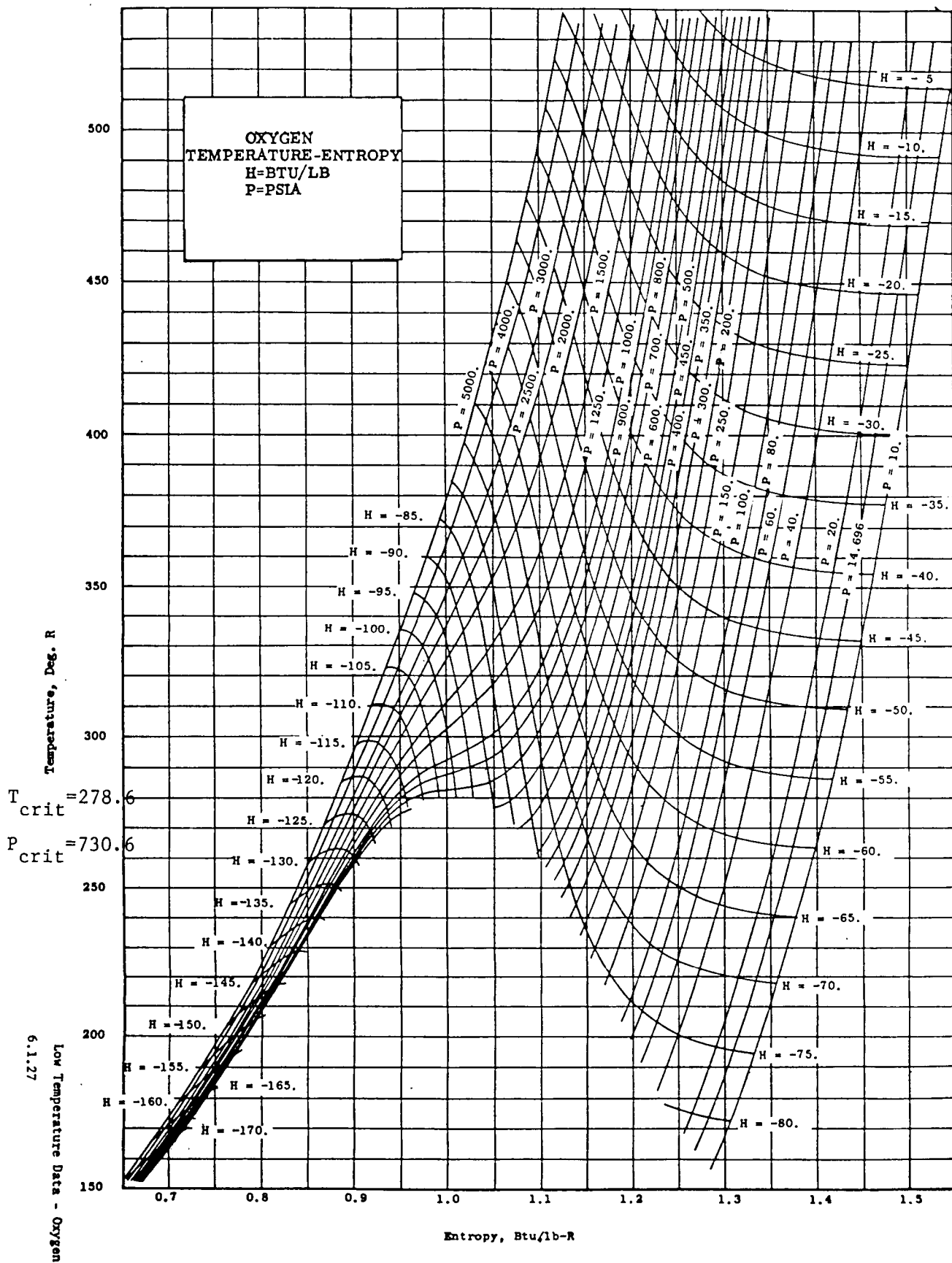












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